**Final**

# Hydrology, Hydraulics, and Water Management Technical Report

**Shasta Lake Water Resources Investigation, California**

*Prepared by:*

**United States Department of the Interior**
**Bureau of Reclamation**
**Mid-Pacific Region**

**December 2014**

*This page left blank intentionally.*

# Contents

**Chapter 1 Affected Environment ..... 1-1**
1.1 Environmental Setting ..... 1-1
1.1.1 Storage and Diversion Facilities ..... 1-8
1.1.2 Hydrology and Hydraulics ..... 1-11
1.1.3 Surface Water Supply ..... 1-33
1.1.4 Groundwater Resources ..... 1-42
1.1.5 Flood Management ..... 1-47
1.1.6 South Delta Water Levels ..... 1-56

**Chapter 2 Modeling Results ..... 2-1**

**Chapter 3 References ..... 3-1**
3.1 Personal Communications ..... 3-3
3.1.1 Chapter 1 Affected Environment ..... 3-3

# Tables

Table 1-1. Pertinent Data – Shasta Dam and Reservoir ..... 1-9
Table 1-2. Historical Average Monthly Precipitation in the Primary Study Area ..... 1-12
Table 1-3. Travel Times of Major Sacramento Valley Rivers ..... 1-13
Table 1-4. Key Locations Along Major Central Valley Rivers ..... 1-15
Table 1-5. Historical Inflows to Shasta Lake ..... 1-16
Table 1-6. Historical End-of-Month Shasta Lake Storage by Year Type ..... 1-17
Table 1-7. Historical End-of-Month Shasta Lake Reservoir Water Surface Elevations by Year Type ..... 1-18
Table 1-8. Historical Shasta Lake Releases by Year Type ..... 1-18
Table 1-9. Historical Spring Creek Tunnel Flow to Keswick Reservoir by Year Type ..... 1-20
Table 1-10. Historical Clear Creek Flow to the Sacramento River by Year Type ..... 1-20
Table 1-11. Historical Major Tributary Inflows to the Sacramento River Between Keswick Dam and Red Bluff Pumping Plant ..... 1-21
Table 1-12. Historical Sacramento River Flow Above Red Bluff Pumping Plant at Bend Bridge by Year Type ..... 1-22
Table 1-13. Historical Diversions to the Tehama-Colusa Canal from Red Bluff Pumping Plant by Year Type ..... 1-22
Table 1-14. Historical Sacramento River Flows at Colusa by Year Type ..... 1-24
Table 1-15. Historical Sacramento River Flows Below Wilkins Slough, near Grimes by Year Type ..... 1-24
Table 1-16. Historical Sacramento River Flows at Verona by Year Type ..... 1-25
Table 1-17. Average Monthly Historical Sacramento River Flows at Rio Vista by Year Type ..... 1-26

Table 1-18. Total Historical Delta Inflow by Year Type ..... 1-27
Table 1-19. Historical Exports from the C.W. "Bill" Jones Pumping Plant by Year Type ..... 1-27
Table 1-20. Historical Exports from the Harvey O. Banks Pumping Plant by Year Type ..... 1-28
Table 1-21. Historical Exports from the Contra Costa Water District Rock Slough Pumping Plant by Year Type ..... 1-29
Table 1-22. Calculated Historical Delta Outflow by Year Type ..... 1-30
Table 1-23. Historical End-of-Month CVP San Luis Storage by Year Type ..... 1-32
Table 1-24. Historical End-of-Month SWP San Luis Storage by Year Type ..... 1-33
Table 1-25. Summary of CVP Contract Amounts for Service Areas South of the Delta ..... 1-35
Table 1-26. Historical CVP Annual Allocations ..... 1-39
Table 1-27. Maximum Annual SWP Table A Amounts ..... 1-40
Table 1-28. Historical Annual SWP Deliveries ..... 1-42
Table 1-29. Groundwater Quality Data for the Various Groundwater Basins Throughout California ..... 1-44
Table 1-30. Historical Shasta Dam and Reservoir Flood Management Operations ..... 1-50
Table 1-31. Percentage of Years with Flows in Excess of Specified Flow Rate for Sacramento River Below Bend Bridge by Month (1939-2010) ..... 1-51
Table 1-32. Number of Years with Spills over Sacramento Valley Weirs ..... 1-55

# Figures

Figure 1-1. Shasta Lake Water Resources Investigation Primary Study Area, Shasta Lake Area and Shasta Dam to Red Bluff Pumping Plant ..... 1-3
Figure 1-2. Shasta Lake Water Resources Investigation Extended Study Area, Lower Sacramento River to the Delta ..... 1-4
Figure 1-3. Shasta Lake Water Resources Investigation Extended Study Area, Delta ..... 1-5
Figure 1-4. Shasta Lake Water Resources Investigation Extended Study Area, South-of-the-Delta ..... 1-6
Figure 1-5. Shasta Lake Water Resources Investigation Extended Study Area, CVP/SWP Service Areas ..... 1-7
Figure 1-6. Sacramento Valley Flood Management Facilities ..... 1-48

# Exhibits

Table A-1. Description of Groundwater Basins and Subbasins in the Primary Study Area ..... A-1
Table A-2. Description of Groundwater Basins and Subbasins in the Extended Study Area ..... A-11
Exhibit B-1. Shasta Dam Flood Management Diagram .....B-1

# Abbreviations and Acronyms

| | |
|---|---|
| ACID | Anderson-Cottonwood Irrigation District |
| AFB | Air Force Base |
| Banks | Harvey O. Banks Pumping Plant |
| Cal/EPA | California Environmental Protection Agency |
| CCWD | Contra Costa Water District |
| CDEC | California Data Exchange Center |
| cfs | cubic feet per second |
| CVP | Central Valley Project |
| CVPIA | Central Valley Project Improvement Act |
| cy | cubic yards |
| Delta | Sacramento-San Joaquin Delta |
| DSM2 | Delta Simulation Model 2 |
| DWR | California Department of Water Resources |
| elevation xxx | elevation in feet above mean sea level |
| EPA | U.S. Environmental Protection Agency |
| FC&WCD | Flood Control and Water Conservation District |
| FCD | Flood Control District |
| Gianelli | William R. Gianelli Pumping-Generating Plant |
| H&H | hydrology, hydraulics, and water management |
| hp | horsepower |
| ID | Irrigation District |
| Jones | C.W. “Bill” Jones Pumping Plant |
| kW | kilowatt |
| M&I | municipal and industrial |
| MAF | million acre-feet |
| MCL | maximum contamination levels |
| mg/L | milligrams per liter |
| msl | mean sea level |
| MW | megawatt |
| MWD | Municipal Water District |
| MWDSC | Metropolitan Water District of Southern California |
| PG&E | Pacific Gas and Electric Company |
| R. | river |
| RBPP | Red Bluff Pumping Plant |
| Reclamation | U.S. Department of the Interior, Bureau of Reclamation |
| RM | river mile |
| ROD | Record of Decision |
| SBA | South Bay Aqueduct |

| | |
|---|---|
| SLWRI | Shasta Lake Water Resources Investigation |
| sq-mi | square mile |
| SWP | State Water Project |
| State Water Board | State Water Resources Control Board |
| TAF | thousand acre-feet |
| TCD | temperature control device |
| TDS | total dissolved solids |
| USACE | U.S. Army Corps of Engineers |
| USGS | U.S. Geological Survey |
| WA | Water Agency |
| WD | Water District |
| WSD | Water Storage District |
| WY | Water Year |

*This page left blank intentionally.*

# Chapter 1
# Affected Environment

This chapter describes the affected environment related to hydrology, hydraulics, and water management (H&H) for the dam and reservoir modifications proposed under the Shasta Lake Water Resources Investigation (SLWRI).

## 1.1 Environmental Setting

The environmental setting section first presents background information and then describes reservoir facilities and operations, H&H, including surface water supply, groundwater resources, flood management facilities, and southern Sacramento-San Joaquin Delta (Delta) water levels.

Shasta Dam and Reservoir are located on the upper Sacramento River in Northern California, about 9 miles northwest of the City of Redding in Shasta County on the Sacramento River. The Shasta Dam and Reservoir project was constructed by the U.S. Department of the Interior, Bureau of Reclamation (Reclamation), as an integral element of the Central Valley Project (CVP) for six purposes: irrigation water supply, municipal and industrial (M&I) water supply, flood management, hydropower generation, fish and wildlife conservation, and navigation.

The CVP was authorized as a Federal Reclamation project in 1935. The dam was constructed between September 1938 to June 1945, when it was put into interim operation. Storage of water in Shasta Reservoir began in December 1943. Gates, valves, and other items of finish work, deferred during the war, were completed and placed in full operation in April 1949. Shasta Reservoir delivers about 55 percent of the total annual water supply developed by the CVP.

Keswick Dam and Reservoir are an integral element of the Shasta Dam and Reservoir Project. Keswick Dam is located on the Sacramento River just north of Redding. All releases from Shasta Dam on the Sacramento River and through the Spring Creek Tunnel from Whiskeytown Reservoir on Clear Creek flow through Keswick Dam.

Below Shasta Dam, the Sacramento River flows through about 60 miles of natural channel along a low foothill area to Red Bluff. From Red Bluff, the Sacramento River flows through natural channels and leveed river reaches for another 250 miles to the Delta.

This Technical Report describes pertinent hydrologic and hydraulic conditions and water management operations for Shasta Lake, the Sacramento River, the Delta, and the CVP/State Water Project (SWP) service areas, under existing conditions, the No-Action Alternative, and the Action Alternatives for the SLWRI.

For purposes of this Technical Report, the area around Shasta Lake and along the Sacramento River from Shasta Dam to Red Bluff is considered the primary study area, as shown in Figure 1-1. The area along the Sacramento River from Red Bluff to the Delta, shown in Figures 1-2 and 1-3, and CVP/SWP service areas shown in Figures 1-4 and 1-5 are considered the extended study area.

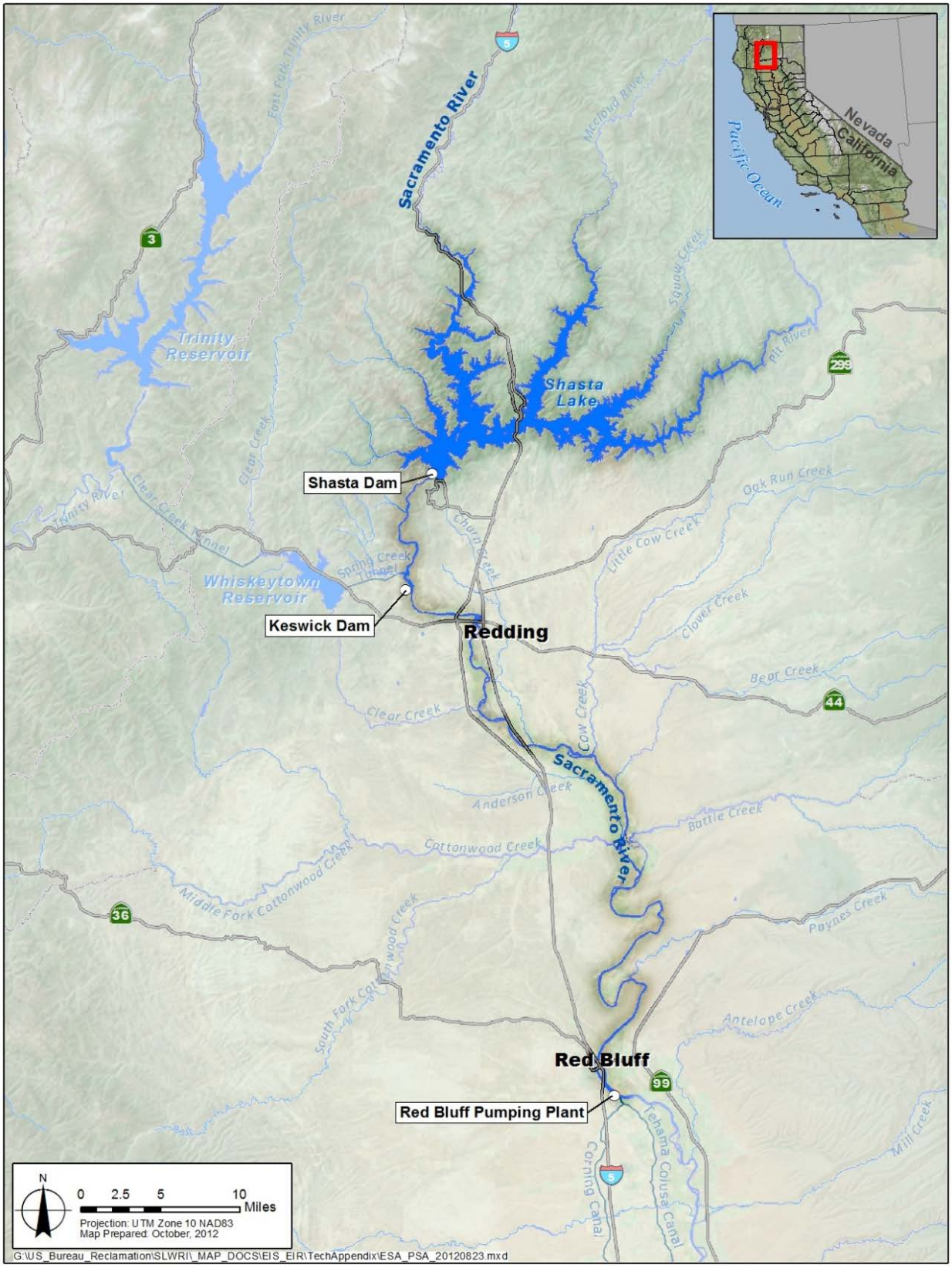


**Figure 1-1. Shasta Lake Water Resources Investigation Primary Study Area, Shasta Lake Area and Shasta Dam to Red Bluff Pumping Plant**

Bend Bridge

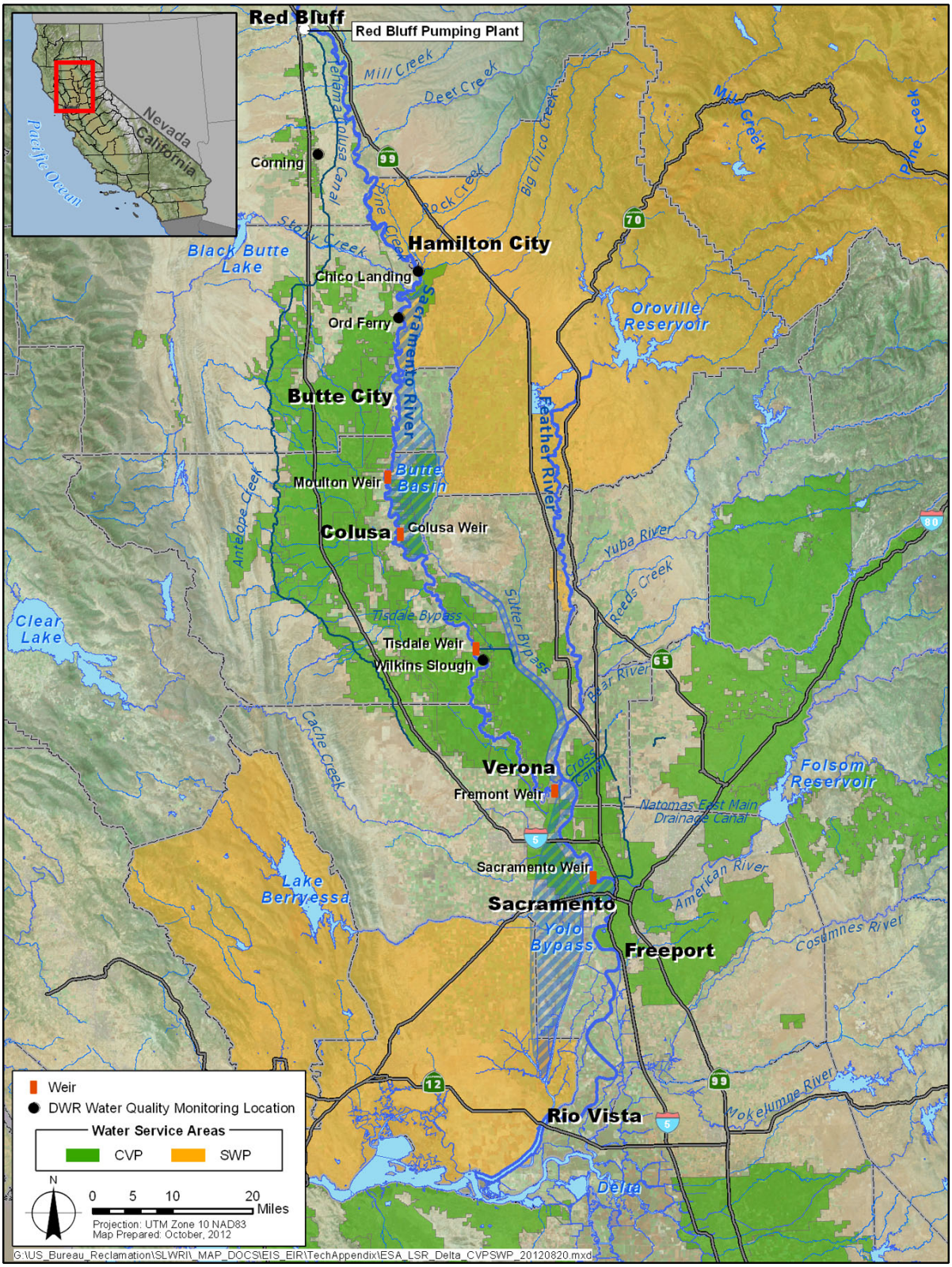


**Figure 1-2. Shasta Lake Water Resources Investigation Extended Study Area, Lower Sacramento River to the Delta**

**Figure 1-3. Shasta Lake Water Resources Investigation Extended Study Area, Delta**

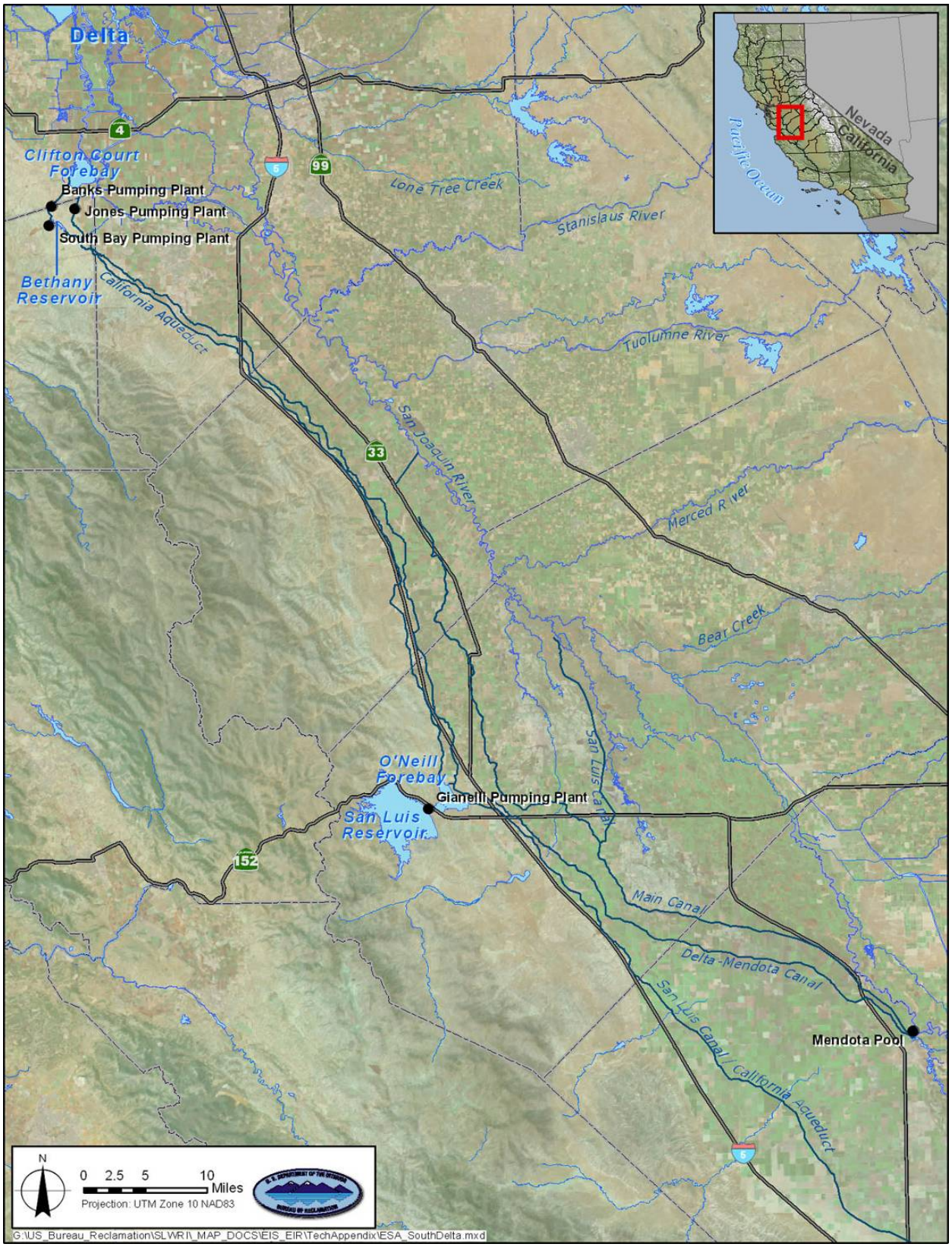


**Figure 1-4. Shasta Lake Water Resources Investigation Extended Study Area, South-of-the-Delta**

**Figure 1-5. Shasta Lake Water Resources Investigation Extended Study Area, CVP/SWP Service Areas**

### 1.1.1 Storage and Diversion Facilities

Facilities described below include Shasta Dam and Powerplant, Keswick Dam and Powerplant, Anderson-Cottonwood Irrigation District (ACID) Diversion Dam, and Red Bluff Pumping Plant (RBPP).

#### *Shasta Lake and Vicinity*

This section describes storage and diversion facilities in the Shasta Lake area.

**Shasta Dam and Powerplant** Shasta Dam is a curved, gravity-type, concrete structure that rises 533 feet above the streambed with a total height above the foundation of 602 feet. The dam has a crest width of about 41 feet and a length of 3,460 feet. Shasta Reservoir has a storage capacity of 4,550,000 acre-feet, and water surface area at full pool of 29,600 acres. Maximum seasonal flood management storage space in Shasta Reservoir is 1.3 million acre-feet (MAF). The Shasta Powerplant consists of five main generating units and two station service units with a combined capacity of 663,000 kilowatts (kW).

Releases from Shasta Dam can be made through the powerplant, over the spillway, or through the river outlets. The powerplant has a maximum release capacity of nearly 20,000 cubic feet per second (cfs), the river outlets can release a maximum of 81,800 cfs at full pool, and the maximum release over the drum-gated spillway is 186,000 cfs.

The existing temperature control device (TCD) at Shasta Dam, constructed from 1996 to 1998, is a multilevel water intake structure located on the upstream face of the dam. The TCD allows operators to draw water from the top of the reservoir during the winter and spring when surface water temperatures are cool and from deeper in the reservoir in the summer and fall when surface water is warm. It also improves oxygen and sediment levels in downstream river water.

The TCD has improved cold-water management for the benefit of fish, as outlined in the Central Valley Project Improvement Act (CVPIA) and State Water Resources Control Board (State Water Board) water right permits, while concurrently producing water for contract deliveries and power generation.

The Shasta Powerplant is located just below Shasta Dam. Water from the dam is released through five 15-foot penstocks leading to the five main generating units and two station service units. Units 1, 2, and 3 are rated at 125 megawatts (MW); Units 4 and 5 were uprated from 125 MW to 142 MW in 1998 and 1999, respectively.

Table 1-1 summarizes pertinent engineering data for and features of the existing Shasta Dam and Reservoir.

**Table 1-1. Pertinent Data – Shasta Dam and Reservoir**

| General | | | |
|---|---|---|---|
| **Drainage Areas (excluding Goose Lake Basin)** | | **Mean Annual Runoff (1908–2006)** | |
| Sacramento R. at Shasta Dam | 6,421 sq-mi | Sacramento R. at Shasta Dam | 5,737,000 acre-feet |
| Sacramento R. at Keswick | 6,468 sq-mi | Sacramento R. near Red Bluff | 8,421,000 acre-feet |
| Bridge near Red Bluff | 8,900 sq-mi | **Sacramento River Maximum Flows** | |
| Sacramento R. near Ord Ferry | 12,250 sq-mi | At Shasta Lake 16 Jan 1974 | 216,000 cfs |
| Pit R. at Big Bend | 4,710 sq-mi | Near Red Bluff 28 Feb 1940 | 291,000 cfs |
| McCloud R. above Shasta Lake | 604 sq-mi | At Ord Ferry 28 Feb 1940 | 370,000 cfs |
| Sacramento R. at Delta above Shasta Lake | 425 sq-mi | | |
| **Shasta Dam and Reservoir** | | | |
| **Shasta Dam (concrete gravity)** | | **Shasta Reservoir** | |
| Crest elevation | 1,077.5 feet | Full pool elevation (msl) | 1,067.0 feet |
| Freeboard above full pool | 9.5 feet | Minimum operating level | 840.0 feet |
| Height above foundations | 602 feet | Taking line | Irregular |
| Height above streambed | 487 feet | Surface Area | |
| Length of crest | 3,500 feet | Minimum operating level | 6,700 acres |
| Width of crest | 30 feet | Full pool | 29,500 acres |
| Slope, upstream | Vertical | Taking line | 90,000 acres |
| Slope, downstream | 1 on 0.8 | Storage capacity | |
| Volume | 8,430,000 cy | Minimum operating level | 587,000 acre-feet |
| Normal tailwater elevation | 585 feet | Full pool | 4,552,000 acre-feet |
| **Spillway (gated ogee)** | | **Shasta Powerplant** | |
| Crest length | | Main units | |
| Gross | 360 feet | 5 turbines, Francis type | 515,000 hp (total) |
| Net | 330 feet | 5 units @ 142 MW | 710 MW (total) |
| Crest gates (drum type) | | Station units | |
| Number and size | 3 @ 110 feet x 28 feet | 2 generators, 2,000 kW each | 4,000 kW (total) |
| Top elevation when lowered | 1037.0 feet | Elevation centerline turbines | 586 feet |
| Top elevation when raised | 1065.0 feet | Maximum tailwater elevation | 632.5 feet |
| Discharge capacity at pool (1,065 feet) | 186,000 cfs | Total discharge at pool (1,065 feet) | 14,500 cfs |
| Flashboard gates | 3 @ 110 feet x 2 feet | Total discharge at pool (827.7 feet) | 16,000 cfs |
| Top elevation when lowered | 1,067.0 feet | Power outlets (15-foot-diameter steel penstocks) | |
| Bottom elevation when raised | 1,069.5 feet | 5 with invert elev. of intake | 807.5 feet |
| **Outlets** 102-inch-diameter conduit with 96-inch-diameter wheel-type gate | | | |
| 4 with invert elevation | 737.75 feet | Capacity at Elevation 1,065 feet | 81,800 cfs |
| 8 with invert elevation | 837.75 feet | Capacity at Elevation 827.7 feet | 12,200 cfs |
| 6 with invert elevation | 937.75 feet | | |

Notes:
Elevations given are in vertical datum NGVD 1929.

Key:
cfs = cubic feet per second
cy = cubic yard
elevation = elevation in feet above msl
hp = horsepower
kW = kilowatt
msl = mean sea level
MW = megawatt
R. = river
sq-mi = square mile

**Keswick Dam and Powerplant** Keswick Dam is about 9 miles downstream from Shasta Dam. In addition to regulating outflow from the dam, Keswick Dam controls runoff from 45 square miles of drainage area. Keswick Dam is a concrete, gravity-type structure with a spillway over the center of the dam. The spillway has four 50-foot by 50-foot fixed wheel gates with a combined discharge capacity of 248,000 cfs at full or full pool elevation (elevation in feet above mean sea level (msl)) (587 feet). Storage capacity below the top of the spillway gates at full pool is 23,800 acre-feet. The powerplant has a nameplate generating capacity of 75,000 kW and can pass about 15,000 cfs at full pool.

**Diversion Facilities** Below Keswick Dam, two facilities, divert flows from the Sacramento River and the ACID Diversion Dam. The primary purpose of these two facilities is to divert water into canals for local agricultural use.

*Anderson-Cottonwood Irrigation District Diversion Dam* Since 1916, water has been diverted into the ACID canal for irrigation along the west side of the Sacramento River between Redding and Cottonwood. Reclamation and ACID have signed a settlement agreement quantifying the amount of water ACID could divert from the Sacramento River. ACID diverts to its main canal on the right bank of the river from a diversion dam in Redding about 5 miles downstream from Keswick Dam. The diversion dam consists of boards supported by a pinned steel superstructure anchored to a concrete foundation across the river. The boards are manually set from a walkway supported by the steel superstructure. The number of boards set in the dam varies depending on the flow in the river and the desired head in the canal.

Because this dam is a flashboard dam installed for seasonal use only, close coordination is required between Reclamation and ACID for regulation of river flows to allow safe installation and removal of the flashboards. The contract between Reclamation and ACID allows for ACID to notify Reclamation as far in advance as is reasonably possible each time ACID intends to install or remove boards from its diversion dam. Reclamation will similarly notify ACID each time it intends to change releases at Keswick Dam. In addition, during the irrigation season, ACID will notify Reclamation of the maximum flow that it believes the diversion dam, with the current setting of boards, can safely accommodate. Reclamation will notify ACID at least 24 hours in advance of a change in releases at Keswick Dam that exceed such maximum flow designated by ACID.

The irrigation season for ACID runs from April through October. Therefore, around April 1 each year, ACID erects the diversion dam. This consists of raising the steel superstructure, and installing the walkway and setting boards. Around November 1 each year, the diversion dam is removed. The dates of installation and removal can vary depending on hydrologic conditions. Removal and installation of the dam cannot be done safely at flows greater than 6,000 cfs. ACID usually requests Reclamation to limit the Keswick release to a 5,000 cfs maximum for 5 days to accomplish the installation or removal of the

dam. As indicated previously, there may be times during the irrigation season when the setting of boards must be changed because of changes in releases at Keswick Dam. When boards must be removed because of an increase at Keswick Dam, the release may initially have to be decreased to allow work to be done safely. If an emergency exists, personnel from Reclamation's Northern California Area Office can be dispatched to assist ACID in removing the boards.

The Keswick Dam release rate ramping required for ACID operations is limited to 15 percent in a 24-hour period and 2.5 percent in a 1-hour period. Therefore, advance notification is important when scheduling decreases to allow installation or removal of the ACID dam. Since 2001, ACID has completed improvements to the ACID Diversion Dam fish ladder, improving passage for winter-run Chinook salmon oncorhynchus tshawytsoha, and to the ACID diversion canal fish screen.

*Red Bluff Pumping Plant* The RBPP, located on the Sacramento River approximately 2 miles southeast of Red Bluff, replaces the Red Bluff Diversion Dam as part of a Fish Passage Improvement Project. The facility includes a 1,118-foot-long flat-plate fish screen, intake channel, 2,500 cfs capacity pumping plant and discharge conduit to divert water from the Sacramento River into the Tehama-Colusa and Corning canals. The facility became operational in 2012.

The Tehama-Colusa Canal is a lined canal extending 111 miles south from the RBPP to provide irrigation service on the west side of the Sacramento Valley in Tehama, Glenn, Colusa, and northern Yolo counties. Construction on the Tehama-Colusa Canal began in 1965, with enlargement approved in 1967, first operation in 1976, and completion in 1980.

### 1.1.2 Hydrology and Hydraulics

The Sacramento Valley contains the Sacramento, Feather, and American river basins, covering an area of more than 24,000 square miles in the northern portion of the Central Valley. The Sacramento Valley also encompasses three major drainage basins: the McCloud River, Pit River, and the Sacramento River in the north; the Delta in the south; the Sierra Nevada Mountains and Cascade Ranges in the east; and the Coast Ranges and Klamath Mountains in the west. Drainage in the northern portion of the Central Valley is provided by the Sacramento, Feather, and American rivers, and major and minor streams and rivers that drain the east and west sides of the valley.

The Sacramento River flows generally north to south from its origin near Mount Shasta to its mouth at the Delta. As the Sacramento River travels to the Delta, it picks up additional flows from the Feather and American rivers. The Feather River flows generally north to south from its origin near Lassen Peak and joins the Sacramento River from the east at Verona. The American River originates

in the Sierra Nevada, flows generally east to west, and enters the Sacramento River at the City of Sacramento at I Street.

Ground surface elevations in the northern portion of the Sacramento Valley range from about 1,070 feet at Shasta Lake to about 14,000 feet above msl (elevation 14,000) in the headwaters of the Sacramento River. In this area, total annual precipitation averages between 60 and 70 inches and is as great as 95 inches in the Sierra Nevada and Cascade Range. At Lassen Peak, which exceeds elevation 10,000 in the Cascade Range, annual precipitation averages as much as 90 inches. Other mountainous areas bordering the valley reach elevations higher than 5,000 and receive an average of 42 inches of precipitation per year, with snow prevalent at higher elevations. In the southern portion of the Sacramento River Basin, the Sacramento Valley floor is relatively flat; elevations range from msl to about 300. The valley floor is characterized by hot, dry summers and mild winters. Precipitation on the valley floor occurs mostly as rain, and average yearly totals range from 20 inches in the northern end of the valley to 15 inches at the Delta. Historical average precipitation at locations along the Sacramento River is shown in Table 1-2.

**Table 1-2. Historical Average Monthly Precipitation in the Primary Study Area**

| Month | Mount Shasta City[1] Elevation 3,544 ft-msl | | Redding[2] Approximate Elevation 500 ft-msl | | Sacramento[3] Approximate Elevation 20 ft-msl | |
|---|---|---|---|---|---|---|
| | (inches) | (% of annual) | (inches) | (% of annual) | (inches) | (% of annual) |
| October | 2.2 | 5.5 | 2.2 | 5.6 | 0.9 | 5.2 |
| November | 5.3 | 13.2 | 4.7 | 11.9 | 2.1 | 12.1 |
| December | 6.7 | 16.7 | 7.0 | 17.7 | 3.0 | 17.2 |
| January | 7.1 | 17.7 | 8.0 | 20.2 | 3.6 | 20.7 |
| February | 6.2 | 15.4 | 5.9 | 14.9 | 3.1 | 17.8 |
| March | 5.3 | 13.2 | 5.0 | 12.6 | 2.4 | 13.8 |
| April | 2.9 | 7.2 | 3.0 | 7.6 | 1.2 | 6.9 |
| May | 1.9 | 4.7 | 1.5 | 3.8 | 0.5 | 2.9 |
| June | 1.0 | 2.5 | 1.0 | 2.5 | 0.2 | 1.1 |
| July | 0.4 | 1.0 | 0.2 | 0.5 | 0.0 | 0.0 |
| August | 0.4 | 1.0 | 0.3 | 0.8 | 0.1 | 0.6 |
| September | 0.8 | 2.0 | 0.8 | 2.0 | 0.3 | 1.7 |
| Total | 40.2 | 100 | 39.6 | 100 | 17.4 | 100 |

*Source: Western Regional Climate Center,*

Notes:
[1] Period of Record (1948-present)
[2] Period of Record (1931-1979)
[3] Period of Record (1948-present)
Key:
ft-msl = feet above mean sea level

The Sacramento River system is complex. There are numerous Federal, State, local, and private dams in the foothills with reserved flood storage space on the Sacramento, Feather, and American river systems. These reservoirs collect and manage flows from the upper watersheds, but many tributaries enter downstream from the dams, and the flow from the downstream tributaries is mostly unregulated. It takes about 70 hours (almost 3 days) for water released from Shasta Dam on the northern portion of the Sacramento River to reach the Feather River confluence at Verona, and about 78 hours (more than 3 days) to reach the American River confluence at I Street in the City of Sacramento. Table 1-3 shows the estimated travel times of high flows in the Sacramento River and major tributaries.

**Table 1-3. Travel Times of Major Sacramento Valley Rivers**

| Location | Travel Time (hours) |
|---|---|
| **Sacramento River** | |
| Shasta Dam | 0 |
| Keswick Dam | 8 |
| Bend Bridge | 18 |
| Red Bluff | 20 |
| Tehama | 26 |
| Hamilton City | 31 |
| Ord Ferry | 36 |
| Butte City | 44 |
| Moulton Weir | 52 |
| Colusa Weir | 53 |
| Colusa | 55 |
| Tisdale Weir | 62 |
| Verona | 70 |
| I Street Gage | 78 |
| **American River** | |
| Nimbus | 0 |
| I Street | 8 |
| **Feather River** | |
| Oroville | 0 |
| Verona | 30 |
| **Yuba River** | |
| Narrows | 0 |
| Yuba City | 8 |

*Source: USACE 1999*

Downstream from Shasta Dam, the Sacramento River flows south-southeast for 65 river miles, until it reaches the valley floor south of Red Bluff. Along the valley floor, the river continues to flow south-southeast for 186 river miles to the City of Sacramento, where it changes to a southwesterly course and flows for an additional 60 river miles to its terminus at Suisun Bay in the Delta. Through the valley floor reach, the Sacramento River is flanked by overflow basins, two of which are leveed floodways. These floodways comprise part of the comprehensive flood management improvements that have been developed along the lower 175 miles of the river on the east bank, along the lower 185 miles of the west bank, and along the lower reaches of the river's major tributary streams. These floodways intercept all Sacramento River tributaries for more than 100 miles downstream from Stony Creek and Big Chico Creek to the Feather River. Downstream from Sacramento, the Sacramento River traverses the low-lying tidal area of the Delta. The Delta area is affected by tidal flow, and this tidal influence extends up the Sacramento River for up to 80 miles (or as far as Verona), during periods of low river flow. Locations along the Sacramento River are referenced by river mile (RM), with RM 0 at Collinsville, the river mouth, and RM 302 at Keswick Dam, as shown in Table 1-4.

**Table 1-4. Key Locations Along Major Central Valley Rivers**

| Location | River Mile |
|---|---|
| **Sacramento River** | |
| Keswick Dam | 299 |
| Redding | 296 |
| Balls Ferry Bridge | 273 |
| Bend Bridge | 255 |
| Red Bluff | 241 |
| Los Molinos | 236 |
| Tehama | 226 |
| Hamilton City | 199 |
| Chico Landing | 194 |
| Stony Creek | 192 |
| Ord Ferry | 184 |
| Butte City | 169 |
| Moulton Weir | 158 |
| Colusa Weir | 146 |
| Colusa | 143 |
| Meridian | 134 |
| Grimes | 125 |
| Tisdale Weir | 119 |
| Knights Landing | 90 |
| Fremont Weir | 83 |
| Feather River | 80 |
| Verona | 79 |
| Natomas Cross Canal | 79 |
| Sacramento Weir | 63 |
| American River | 60 |
| I Street Gage | 59.5 |
| Deep Water Ship Channel (north end) | 57 |
| Clarksburg | 42 |
| Courtland | 34 |
| Walnut Grove | 27 |
| Isleton | 18 |
| Liberty Island | 14 |
| Rio Vista | 12 |
| Collinsville | 0 |
| **Feather River** | |
| Oroville Dam | 70.4 |
| Oroville Gaging Station | 65.3 |
| Mouth | 0.0 |
| **Yuba River** | |
| Englebright Dam | 22.8 |
| Mouth | 0.0 |
| **American River** | |
| Folsom Dam | 26 |
| Mouth | 0.0 |

Source: USACE 1999

### *Shasta Lake and Vicinity*

The most northern portion of the Sacramento River basin, upstream from Shasta Dam, is drained by the Pit River, the McCloud River, Squaw Creek, and the headwaters of the Sacramento River. The total drainage area is about 6,700 square miles, excluding the Goose Lake drainage of the Pit River. Although Goose Lake is topographically within the Pit River Basin, it seldom contributes to flow in the Pit River. The last outflow from Goose Lake occurred in 1880. Only a small Federal levee project in Alturas is found in this segment of the Sacramento River drainage.

The four major tributaries to Shasta Lake are the Sacramento, McCloud, and Pit rivers, and Squaw Creek, in addition to numerous minor tributary creeks and streams. The combined historical average monthly inflows to Shasta Lake from three major tributaries (Sacramento, McCloud, and Pit rivers) are shown in Table 1-5.

**Table 1-5. Historical Inflows to Shasta Lake**

| | Average Monthly Inflow (cfs) | | | | | | | | | | | | Annual Total (TAF) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Oct | Nov | Dec | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | |
| Sacramento River at Delta[1] | 340 | 727 | 1,359 | 1,900 | 2,331 | 2,275 | 2,051 | 1,768 | 857 | 349 | 240 | 233 | 870 |
| Pit River[1] | 3,092 | 3,615 | 4,404 | 5,696 | 6,445 | 6,868 | 6,154 | 5,036 | 3,693 | 2,972 | 2,795 | 2,819 | 3,239 |
| McCloud River[2] | 587 | 777 | 1,266 | 1,629 | 1,861 | 1,770 | 1,470 | 1,120 | 765 | 590 | 531 | 521 | 766 |
| Total | 4,020 | 5,119 | 7,028 | 9,226 | 10,637 | 10,913 | 9,676 | 7,924 | 5,314 | 3,911 | 3,566 | 3,574 | 4,875 |

*Source: USGS Gaging Stations 11342000, 11365000, 11368000*

Notes:

[1] Period of record WY 1945–2010

[2] Period of record WY 1946–2010

Key:

cfs = cubic feet per second

TAF = thousand acre-feet

USGS = United States Geological Survey

WY = water year

The Sacramento Arm above Shasta Lake drains an area of roughly 430 square miles. Its headwaters include portions of Mount Shasta and the Trinity and Klamath mountains. It flows south for approximately 40 miles before entering Shasta Lake below the town of Delta.

**McCloud River** The McCloud River drainage basin covers approximately 627 square miles of Siskiyou and Shasta counties. The McCloud River originates as Moosehead Creek southeast of Mount Shasta, at an elevation of approximately 5,500. From there, it flows approximately 59 miles in a southwesterly direction through McCloud Reservoir before entering Shasta Lake and joining the Sacramento River. The McCloud Reservoir watershed includes the entire basin draining into McCloud Reservoir and has a drainage area of 403 square miles. The lower McCloud River watershed begins at Pacific Gas and Electric

Company's (PG&E) McCloud Dam, extends down the McCloud River into Shasta Lake, and encompasses approximately 224 square miles.

**Pit River** The Pit River watershed is located in northeastern California and southeastern Oregon. The north and south forks of the Pit River drain the northern portion of the watershed. The north fork of the Pit River originates at the outlet of Goose Lake and the south fork originates in the south Warner Mountains at Moon Lake in Lassen County. The Pit River is joined by the Fall River in Shasta County. The Pit River has 21 named tributaries, totaling about 1,050 miles of perennial stream and encompassing approximately 4,700 square miles. PG&E has several dams and reservoirs within the Pit River watershed, including Iron Canyon Reservoir, and Pit 4, 5, 6, and 7 dams. Pit 7 Dam and Powerhouse are located immediately upstream from Shasta Reservoir's current high-water level on the Pit River.

**Squaw Creek** The Squaw Creek watershed is located east of Shasta Lake and drains 103 square miles. It flows to the southwest through generally steep terrain.

**Shasta Lake** Shasta Lake reservoir storage is typically at its highest in April and May and at its lowest in October and November. Table 1-6 shows the historical average end-of-month reservoir storage at Shasta Lake since 1954 by year type.[1] Table 1-7 shows historical average end-of-month Shasta Lake reservoir water surface elevations since 1992 by year type.

**Table 1-6. Historical End-of-Month Shasta Lake Storage by Year Type**

| Year Type | Average End-of-Month Storage (TAF) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Oct | Nov | Dec | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep |
| All Years | 2,462 | 2,475 | 2,717 | 3,055 | 3,384 | 3,683 | 3,935 | 3,956 | 3,675 | 3,204 | 2,831 | 2,625 |
| Wet | 2,796 | 2,853 | 3,152 | 3,513 | 3,641 | 3,813 | 4,131 | 4,311 | 4,125 | 3,696 | 3,293 | 3,085 |
| Above Normal | 2,387 | 2,389 | 2,739 | 3,208 | 3,527 | 3,869 | 4,290 | 4,372 | 4,113 | 3,604 | 3,251 | 3,070 |
| Below Normal | 2,399 | 2,382 | 2,562 | 3,102 | 3,635 | 3,887 | 4,225 | 4,164 | 3,820 | 3,313 | 2,951 | 2,751 |
| Dry | 2,378 | 2,407 | 2,648 | 2,836 | 3,289 | 3,746 | 3,804 | 3,656 | 3,225 | 2,676 | 2,305 | 2,103 |
| Critical | 2,048 | 1,990 | 2,016 | 2,193 | 2,638 | 2,958 | 3,053 | 2,951 | 2,693 | 2,315 | 1,968 | 1,723 |

*Source: DWR CDEC Gage SHA (2008)*

Notes:
Period of record WY 1992–2010
Year types as defined in the Sacramento Valley Water Year Hydrologic Classification Index
Key:
CDEC = California Data Exchange Center
DWR = California Department of Water Resources
TAF = thousand acre-feet
WY = water year

[1] Throughout this document, water year types are defined according to the Sacramento Valley Index Water Year Hydrologic Classification unless specified otherwise.

**Table 1-7. Historical End-of-Month Shasta Lake Reservoir Water Surface Elevations by Year Type**

| Year Type | Average End-of-Month Water Surface Elevation (ft-msl) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Oct | Nov | Dec | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep |
| All Years | 979 | 980 | 994 | 1,007 | 1,023 | 1,035 | 1,045 | 1,045 | 1,033 | 1,014 | 996 | 986 |
| Wet | 997 | 1,000 | 1,015 | 1,030 | 1,034 | 1,041 | 1,053 | 1,059 | 1,051 | 1,035 | 1,018 | 1,010 |
| Above Normal | 976 | 977 | 1,006 | 1,016 | 1,030 | 1,043 | 1,058 | 1,061 | 1,051 | 1,032 | 1,018 | 1,010 |
| Below Normal | 975 | 975 | 984 | 1,011 | 1,033 | 1,044 | 1,056 | 1,053 | 1,040 | 1,020 | 1,004 | 994 |
| Dry | 974 | 976 | 988 | 996 | 1,019 | 1,038 | 1,040 | 1,034 | 1,016 | 992 | 973 | 962 |
| Critical | 956 | 952 | 954 | 964 | 990 | 1,005 | 1,009 | 1,005 | 992 | 973 | 954 | 927 |

*Source: DWR CDEC Gage SHA (2010)*

Notes:
Period of record WY 1992–2010
Year types as defined in the Sacramento Valley Water Year Hydrologic Classification Index
Key:
CDEC = California Data Exchange Center
DWR = California Department of Water Resources
ft-msl = feet above mean sea level
WY = water year

As previously described, releases from Shasta Lake to the Sacramento River can be made through either the Shasta Lake Powerplant, with a maximum capacity of about 16,000 cfs; through the river outlets, with a maximum capacity of about 81,000 cfs; or over the dam crest, through the spillway, with a maximum capacity of about 186,000 cfs. Table 1-8 shows historical monthly average releases from Shasta Lake by year type.

**Table 1-8. Historical Shasta Lake Releases by Year Type**

| Year Type | Average Monthly Release (cfs) | | | | | | | | | | | | Annual Total (TAF) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Oct | Nov | Dec | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | |
| All Years | 4,691 | 4,492 | 5,307 | 8,446 | 10,167 | 9,881 | 7,135 | 9,329 | 10,610 | 11,519 | 9,427 | 6,826 | 5,917 |
| Wet | 4,791 | 5,010 | 8,111 | 17,104 | 19,395 | 17,663 | 10,990 | 10,327 | 11,108 | 11,714 | 10,583 | 7,450 | 8,109 |
| Above Normal | 4,524 | 3,954 | 3,739 | 5,826 | 9,371 | 11,073 | 5,828 | 10,845 | 11,035 | 12,259 | 9,142 | 6,623 | 5,702 |
| Below Normal | 4,873 | 4,252 | 5,085 | 4,123 | 10,322 | 7,591 | 4,629 | 8,451 | 11,729 | 11,874 | 9,020 | 6,619 | 5,351 |
| Dry | 4,794 | 4,521 | 3,681 | 4,111 | 2,822 | 3,440 | 6,023 | 8,717 | 11,109 | 12,300 | 9,097 | 6,302 | 4,663 |
| Critical | 4,458 | 4,294 | 4,111 | 3,282 | 2,467 | 2,841 | 4,319 | 6,717 | 7,639 | 8,866 | 8,209 | 6,682 | 3,873 |

*Source: DWR CDEC Gage SHA (2008)*

Notes:
Period of record WY 1992–2007
Year types as defined in the Sacramento Valley Water Year Hydrologic Classification Index
Key:
CDEC = California Data Exchange Center
cfs = cubic feet per second
DWR = California Department of Water Resources
TAF = thousand acre-feet
WY = water year

***Upper Sacramento River (Shasta Dam to Red Bluff)***

Flows in the Sacramento River in the 65-river-mile reach between Shasta Dam and Red Bluff (RM 244) are regulated by Shasta Dam and reregulated downstream at Keswick Dam (RM 302). In this reach, flows are influenced by tributary inflow. Major westside tributaries to the Sacramento River in this reach of the river include Clear and Cottonwood creeks. Major eastside tributaries to the Sacramento River in this reach of the river include Battle, Bear, Churn, Cow, and Paynes creeks.

**Imports from the Trinity River Watershed** Since 1964, Trinity River water has been imported into the Sacramento River Basin through the Clear Creek and Spring Creek tunnels (capacity 3,300 and 4,200 cfs, respectively). After meeting the monthly minimum instream flow requirement below Lewiston Dam,[2] and the Trinity Reservoir end-of-September minimum storage target of 600,000 acre-feet, Trinity River water is diverted into Whiskeytown Reservoir. Monthly diversions are based on the beginning-of-month storage in Shasta Reservoir and Trinity Reservoir. For example, imports can be as much as 3,000 cfs for July to September when Trinity Reservoir storage is high and Shasta Reservoir storage is low. Whiskeytown Reservoir receives inflow from Clear Creek. After making releases to meet the minimum flow requirement downstream from Whiskeytown Dam,[3] water is diverted through Spring Creek Tunnel to Keswick Reservoir. Based on the December 19, 2000, Trinity River Mainstem Record of Decision (ROD), 368,600 acre-feet to 815,000 acre-feet are allocated annually for Trinity River flows (Reclamation 2000). After several challenges and injunctions, on July 13, 2004, the Ninth Circuit Court upheld the Trinity ROD flows for the Trinity River. Historical monthly Spring Creek Tunnel flows to Keswick Reservoir between 1964 and 2004 are shown in Table 1-9. Flows from Clear Creek join the Sacramento River below Keswick Dam. Historical monthly Clear Creek Tunnel flows to the Sacramento River between 1964 and 2004 are shown in Table 1-10 by year type. Since the implementation of the Trinity ROD in 2004, flows in the Spring Creek Tunnel and in Clear Creek have followed a substantially different pattern. Due to the limited available hydrology, average monthly flows since 2004 are also shown in Tables 1-9 and 1-10.

[2] This minimum requirement, an annual amount of 369,000 acre-feet to 815,000 acre-feet per the Trinity Environmental Impact Statement Preferred Alternative, is a lookup value that varies by month and the Trinity index; the Trinity index changes in April.

[3] This requirement is a lookup value that varies with the month and the Shasta Index.

### Table 1-9. Historical Spring Creek Tunnel Flow to Keswick Reservoir by Year Type

| Year Type | Average Monthly Release (cfs) | | | | | | | | | | | | Annual Total (TAF) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Oct | Nov | Dec | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | |
| All Years | 1,559 | 1,179 | 1,063 | 1,337 | 1,638 | 1,659 | 1,370 | 1,524 | 1,987 | 2,419 | 2,318 | 2,150 | 1,217 |
| All Years[1] | 1,354 | 738 | 658 | 726 | 1,077 | 1,000 | 664 | 1,187 | 1,248 | 1,579 | 1,601 | 1,470 | 805 |
| Wet | 1,386 | 1,320 | 1,512 | 2,082 | 2,552 | 2,200 | 2,109 | 2,105 | 2,527 | 2,681 | 2,464 | 2,215 | 1,520 |
| Above Normal | 994 | 847 | 826 | 1,550 | 1,941 | 2,111 | 1,343 | 1,426 | 1,654 | 1,621 | 2,032 | 1,945 | 1,105 |
| Below Normal | 1,790 | 1,472 | 1,425 | 912 | 1,252 | 1,800 | 1,687 | 1,767 | 2,198 | 2,830 | 2,409 | 1,956 | 1,302 |
| Dry | 1,420 | 971 | 605 | 621 | 799 | 992 | 446 | 619 | 1,218 | 2,255 | 2,098 | 2,337 | 845 |
| Critical | 2,393 | 1,109 | 372 | 470 | 406 | 604 | 401 | 1,013 | 1,658 | 2,374 | 2,383 | 2,127 | 929 |

*Source: USGS Gaging Station 11371600*

Notes:
[1] Period of Record is WY 2004–2010
Period of record WY 1964–2004 unless otherwise indicated,
Year- types as defined in the Sacramento Valley Water Year Hydrologic Classification Index
Key:
cfs = cubic feet per second
TAF = thousand acre-feet
USGS = U.S. Geological Survey
WY = water year

### Table 1-10. Historical Clear Creek Flow to the Sacramento River by Year Type

| Year Type | Average Monthly Release (cfs) | | | | | | | | | | | | Annual Total (TAF) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Oct | Nov | Dec | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | |
| All Years | 122 | 181 | 243 | 319 | 343 | 340 | 217 | 124 | 83 | 63 | 63 | 97 | 133 |
| All Years[1] | 218 | 223 | 287 | 345 | 355 | 342 | 337 | 301 | 194 | 125 | 98 | 143 | 179 |
| Wet | 92 | 161 | 285 | 457 | 504 | 557 | 343 | 140 | 80 | 70 | 72 | 142 | 175 |
| Above Normal | 145 | 175 | 247 | 385 | 342 | 290 | 216 | 186 | 114 | 60 | 59 | 73 | 138 |
| Below Normal | 88 | 157 | 157 | 168 | 254 | 166 | 117 | 98 | 78 | 57 | 54 | 66 | 88 |
| Dry | 264 | 336 | 326 | 264 | 248 | 214 | 118 | 97 | 88 | 61 | 59 | 78 | 130 |
| Critical | 56 | 98 | 118 | 90 | 112 | 103 | 83 | 80 | 62 | 55 | 54 | 51 | 58 |

*Source: USGS Gaging Station 11372000*

Notes:
[1] Period of Record is WY 2004–2010
Period of record WY 1964–2004 unless otherwise indicated
Year types as defined in the Sacramento Valley Water Year Hydrologic Classification Index
Key:
cfs = cubic feet per second
TAF = thousand acre-feet
USGS = U.S. Geological Survey
WY = water year

**Tributary Inflows** Major tributaries to the Sacramento River between Keswick Dam and the RBPP include Cow, Battle, and Cottonwood creeks. Inflows from these creeks typically play a large role in Shasta Lake flood management operations due to their uncontrolled nature. Historical average annual flows from these four creeks to the Sacramento River are shown in Table 1-11.

**Table 1-11. Historical Major Tributary Inflows to the Sacramento River Between Keswick Dam and Red Bluff Pumping Plant**

| Tributary | Average Monthly Inflow (cfs) | | | | | | | | | | | | Annual Total (TAF) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Oct | Nov | Dec | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | |
| Cow Creek | 119 | 449 | 1,146 | 1,698 | 1,652 | 1,399 | 888 | 566 | 222 | 63 | 38 | 46 | 500 |
| Cottonwood Creek | 115 | 369 | 1,210 | 2,239 | 2,441 | 2,078 | 1,221 | 718 | 330 | 124 | 74 | 79 | 663 |
| Battle Creek | 291 | 388 | 543 | 724 | 724 | 721 | 643 | 625 | 483 | 330 | 263 | 258 | 362 |

*Source: USGS Gaging Stations11374000, 11376000, 11376550*

Notes:
Period of record WY 1962–2010

Key:
cfs = cubic feet per second
TAF = thousand acre-feet
USGS = U.S. Geological Survey
WY = water year

**Above Red Bluff Pumping Plant at Bend Bridge** The RBPP pumps into the Tehama-Colusa Canal. Table 1-12 shows the historical average monthly Sacramento River flow above the RBPP at Bend Bridge by year type, and Table 1-13 shows the average monthly historical diversions to the Tehama-Colusa Canal by year type.

**Table 1-12. Historical Sacramento River Flow Above Red Bluff Pumping Plant at Bend Bridge by Year Type**

| Year Type | Average Monthly Release (cfs) | | | | | | | | | | | | Annual Total (TAF) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Oct | Nov | Dec | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | |
| All Years | 6,810 | 6,694 | 10,552 | 17,512 | 20,236 | 18,105 | 12,210 | 13,459 | 13,657 | 14,024 | 11,750 | 8,855 | 9,298 |
| Wet | 6,720 | 7,696 | 14,857 | 32,159 | 33,606 | 30,445 | 19,629 | 16,175 | 15,490 | 15,137 | 13,362 | 10,037 | 13,001 |
| Above Normal | 6,874 | 6,243 | 10,108 | 15,173 | 18,685 | 19,856 | 11,165 | 17,013 | 14,360 | 14,159 | 11,468 | 8,747 | 9,305 |
| Below Normal | 6,985 | 6,095 | 10,055 | 12,859 | 23,001 | 14,935 | 9,746 | 11,122 | 14,382 | 14,242 | 10,914 | 8,376 | 8,607 |
| Dry | 7,018 | 6,589 | 8,280 | 8,318 | 8,789 | 8,193 | 7,781 | 10,554 | 12,850 | 14,545 | 11,429 | 8,257 | 6,818 |
| Critical | 6,509 | 5,832 | 5,894 | 6,699 | 8,981 | 6,420 | 6,316 | 8,718 | 9,646 | 10,777 | 9,885 | 7,751 | 5,650 |

*Source: USGS Gaging Station 11377100*

Notes:
Period of record WY 1992–2010
Year types as defined in the Sacramento Valley Water Year Hydrologic Classification Index
Key:
cfs = cubic feet per second
TAF = thousand acre-feet
USGS = U.S. Geological Survey
WY = Water year

**Table 1-13. Historical Diversions to the Tehama-Colusa Canal from Red Bluff Pumping Plant by Year Type**

| Year Type | Average Monthly Release (cfs) | | | | | | | | | | | | Annual Total (TAF) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Oct | Nov | Dec | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | |
| All Years | 134 | 17 | 7 | 16 | 33 | 85 | 191 | 534 | 949 | 998 | 867 | 313 | 252 |
| Wet | 123 | 18 | 2 | 7 | 45 | 67 | 114 | 450 | 902 | 1,093 | 1,059 | 331 | 257 |
| Above Normal | 145 | 18 | 4 | 24 | 14 | 58 | 215 | 521 | 1,026 | 1,004 | 817 | 329 | 254 |
| Below Normal | 190 | 12 | 0 | 2 | 34 | 80 | 272 | 749 | 1,046 | 914 | 543 | 291 | 245 |
| Dry | 143 | 14 | 12 | 35 | 34 | 165 | 332 | 693 | 1,035 | 916 | 616 | 303 | 264 |
| Critical | 90 | 22 | 43 | 10 | 14 | 42 | 82 | 384 | 648 | 734 | 944 | 204 | 192 |

*Source: Reclamation Central Valley Project Operations Records (2008)*

Notes:
Period of record WY 1992–2007
Year types as defined in the Sacramento Valley Water Year Hydrologic Classification Index
Key:
cfs = cubic feet per second
Reclamation = U.S. Department of the Interior, Bureau of Reclamation
TAF = thousand acre-feet
WY = water year

### *Lower Sacramento River and Delta*

The hydrology and hydraulics of the Sacramento River below Red Bluff and the Delta are described below.

**Lower Sacramento River** The Sacramento River enters the Sacramento Valley about 5 miles north of Red Bluff. Over the 244 miles between Red Bluff downstream to the Delta, the river goes through a series of changes. From Red Bluff to Chico Landing (52 miles), the river meanders through alluvial deposits and receives flows from Antelope, Mill, Deer, Big Chico, Rock, and Pine creeks on the east side and Thomes, Elder, Reeds, and Red Bank creeks on the west side. From Chico Landing to Colusa (50 miles) the Sacramento River meanders through alluvial deposits between widely spaced levees. Stony Creek is the only major tributary in this segment of the river. There are no tributaries entering the Sacramento River between Stoney Creek and its confluence with the Feather River.

Floodwaters in the Sacramento River overflow the east bank at three sites in a reach referred to by the State as the Butte Basin Overflow Area. In this river reach, several Federal projects begin, including the Sacramento River Flood Control Project, Sacramento River Major and Minor Tributaries Project, and Sacramento River Bank Protection Project. Levees of the Sacramento River Flood Control Project begin in this reach, downstream from Ord Ferry on the west (RM 184), and downstream from RM 176 above Butte City on the east side of the river. Historical monthly average Sacramento River flows at Colusa are shown in Table 1-14 by year type.

Shasta Lake is also operated to meet a flow requirement in the Sacramento River, at Wilkins Slough near Grimes (RM 125). This compliance location is also known as the Navigation Control Point, and is discussed in detail in the Regulatory Setting section. Historical monthly average Sacramento River flows below Wilkins Slough are shown in Table 1-15 by year type.

**Table 1-14. Historical Sacramento River Flows at Colusa by Year Type**

| Year Type | Average Monthly Release (cfs) | | | | | | | | | | | | Annual Total (TAF) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Oct | Nov | Dec | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | |
| All Years | 5,576 | 5,914 | 11,606 | 19,010 | 21,149 | 18,836 | 13,109 | 12,022 | 10,756 | 10,051 | 8,744 | 7,798 | 8,731 |
| Wet | 5,914 | 7,224 | 15,759 | 28,317 | 29,762 | 27,691 | 20,909 | 16,178 | 13,788 | 11,387 | 10,229 | 8,949 | 11,839 |
| Above Normal | 5,307 | 5,195 | 11,657 | 21,913 | 21,802 | 20,311 | 13,534 | 16,178 | 11,771 | 9,968 | 8,628 | 7,684 | 9,304 |
| Below Normal | 5,232 | 4,971 | 11,658 | 17,703 | 22,672 | 18,185 | 11,646 | 9,112 | 10,729 | 9,749 | 7,802 | 7,425 | 8,258 |
| Dry | 5,306 | 5,826 | 9,419 | 10,567 | 12,163 | 11,558 | 6,932 | 7,347 | 8,406 | 10,133 | 8,281 | 7,041 | 6,228 |
| Critical | 5,850 | 4,996 | 6,116 | 8,654 | 14,022 | 9,298 | 6,150 | 6,343 | 6,491 | 7,582 | 7,172 | 6,907 | 5,404 |

*Source: USGS Gaging Station 11389500*

Notes:

Period of record WY 1992–2010

Year types as defined in the Sacramento Valley Water Year Hydrologic Classification Index

Key:
cfs = cubic feet per second
TAF = thousand acre-feet
USGS = U.S. Geological Survey
WY = water year

**Table 1-15. Historical Sacramento River Flows Below Wilkins Slough, near Grimes by Year Type**

| Year Type | Average Monthly Release (cfs) | | | | | | | | | | | | Annual Total (TAF) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Oct | Nov | Dec | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | |
| All Years | 5,561 | 5,828 | 10,848 | 16,110 | 18,141 | 15,976 | 11,751 | 10,383 | 9,378 | 8,580 | 7,663 | 7,690 | 7,724 |
| Wet | 5,770 | 6,842 | 14,214 | 21,438 | 23,171 | 20,967 | 17,403 | 14,317 | 12,319 | 10,013 | 9,133 | 8,759 | 9,923 |
| Above Normal | 5,331 | 5,361 | 10,434 | 19,333 | 19,164 | 17,390 | 13,117 | 14,070 | 10,738 | 8,486 | 7,434 | 7,536 | 8,360 |
| Below Normal | 5,234 | 4,771 | 10,649 | 16,138 | 19,067 | 16,049 | 11,467 | 8,069 | 9,417 | 8,093 | 6,768 | 7,431 | 7,431 |
| Dry | 5,483 | 6,011 | 9,635 | 10,309 | 11,976 | 11,638 | 6,598 | 6,098 | 6,915 | 8,585 | 7,345 | 7,050 | 5,904 |
| Critical | 5,774 | 4,883 | 6,421 | 8,872 | 14,321 | 9,845 | 5,686 | 4,853 | 4,944 | 6,158 | 6,047 | 6,781 | 5,100 |

*Source: USGS Gaging Station 11390500*

Notes:

Period of record WY 1992–2010

Year types as defined in the Sacramento Valley Water Year Hydrologic Classification Index

Key:
cfs = cubic feet per second
TAF = thousand acre-feet
USGS = U.S. Geological Survey
WY = water year

Downstream from Wilkins Slough, the Feather River, the largest eastside tributary to the Sacramento River, enters the river just above Verona. Between Wilkins Slough and Verona, floodwater is diverted at two places in this segment of the river–Tisdale Weir into the Tisdale Bypass and Fremont Weir into the Yolo Bypass. The bypass system routes floodwater away from the mainstem Sacramento River to discharge into the Delta. Historical average monthly Sacramento River flows at Verona are shown in Table 1-16 by year type.

**Table 1-16. Historical Sacramento River Flows at Verona by Year Type**

| Year Type | Average Monthly Release (cfs) | | | | | | | | | | | | Annual Total (TAF) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Oct | Nov | Dec | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | |
| All Years | 9,572 | 10,310 | 19,344 | 31,500 | 35,742 | 31,995 | 22,835 | 19,731 | 16,597 | 15,794 | 15,059 | 14,008 | 14,642 |
| Wet | 10,461 | 11,751 | 27,901 | 47,558 | 54,255 | 48,686 | 38,499 | 30,837 | 23,876 | 18,344 | 17,281 | 16,259 | 20,862 |
| Above Normal | 8,911 | 9,480 | 16,691 | 34,688 | 35,514 | 33,792 | 23,702 | 25,529 | 19,283 | 17,135 | 16,331 | 14,099 | 15,416 |
| Below Normal | 9,314 | 9,617 | 17,717 | 29,729 | 33,565 | 29,934 | 18,284 | 12,214 | 14,910 | 16,229 | 15,974 | 14,775 | 13,419 |
| Dry | 8,955 | 10,442 | 15,141 | 17,850 | 19,059 | 19,377 | 11,364 | 10,308 | 11,014 | 15,560 | 14,218 | 12,369 | 10,021 |
| Critical | 9,674 | 8,822 | 12,457 | 14,515 | 22,718 | 14,418 | 8,679 | 7,366 | 7,024 | 8,926 | 9,428 | 11,057 | 8,145 |

*Source: USGS Gaging Station 11425500*

Notes:
[1] Period of record WY 1992–2010
Year types as defined in the Sacramento Valley Water Year Hydrologic Classification Index
Key:
cfs = cubic feet per second
TAF = thousand acre-feet
USGS = U.S. Geological Survey
WY = water year

Below Verona, the Sacramento River flows 79 miles to the Delta, passing the City of Sacramento. The Yolo Bypass parallels this river reach to the west. Flows enter this river reach at various points. First, flows from the Natomas Cross Canal enter the Sacramento River approximately 1 mile downstream from the Feather River mouth. The American River flows into the Sacramento River in the City of Sacramento. When Sacramento River system flood flows are the highest, a portion of the flow is diverted into the Yolo Bypass at the Sacramento Weir about 3 miles upstream from the American River confluence in downtown Sacramento. At the downstream end, Yolo Bypass flows reenter the Sacramento River near Rio Vista. As the river enters the Delta, Georgiana Slough branches off from the mainstem of the Sacramento River, routing a portion of the flow into the central Delta. Historical monthly average Sacramento River flows in Rio Vista are shown in Table 1-17 by year type.

**Table 1-17. Average Monthly Historical Sacramento River Flows at Rio Vista by Year Type**

| Year Type | Average Monthly Release (cfs) | | | | | | | | | | | | Annual Total (TAF) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Oct | Nov | Dec | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | |
| All Years | 7,797 | 8,854 | 20,470 | 40,713 | 54,324 | 44,833 | 33,925 | 24,465 | 14,920 | 12,459 | 11,090 | 10,256 | 17,119 |
| Wet | 8,823 | 10,774 | 32,191 | 73,740 | 104,708 | 79,546 | 69,207 | 41,787 | 20,719 | 13,610 | 11,591 | 11,062 | 28,739 |
| Above Normal | 8,052 | 8,695 | 17,577 | 33,140 | 40,132 | 41,233 | 24,789 | 28,974 | 17,115 | 13,081 | 11,795 | 10,968 | 15,432 |
| Below Normal | 7,912 | 7,602 | 16,626 | 28,917 | 39,981 | 34,479 | 17,774 | 12,568 | 13,470 | 12,813 | 11,991 | 10,870 | 12,963 |
| Dry | 6,589 | 7,995 | 12,877 | 16,400 | 16,855 | 17,750 | 11,122 | 9,891 | 8,712 | 11,488 | 10,433 | 9,200 | 8,426 |
| Critical | 7,797 | 8,854 | 20,470 | 40,713 | 54,324 | 44,833 | 33,925 | 24,465 | 14,920 | 12,459 | 11,090 | 10,256 | 17,119 |

*Source: USGS Gaging Station 11455420*

Notes:
Period of record WY 1995–2010
Year types as defined in the Sacramento Valley Water Year Hydrologic Classification Index
Key:
cfs = cubic feet per second
TAF = thousand acre-feet
USGS = U.S. Geological Survey
WY = water year

**Delta** The hydraulics of the Delta are complicated by tidal influences, a multitude of agricultural and M&I diversions for use within the Delta itself, and by CVP and SWP exports. The principal factors affecting Delta hydrodynamics are (1) river inflow and outflow from the Sacramento River and San Joaquin River systems, (2) daily tidal inflow and outflow through San Francisco Bay, and (3) export pumping from the south Delta, primarily through the Harvey O. Banks (Banks) and C.W. “Bill” Jones (Jones) pumping plants.

*Delta Inflow* Inflow to the Delta comes from the Sacramento, San Joaquin, Mokelumne, and Cosumnes rivers, and many smaller eastside tributaries. Historical monthly average total Delta inflow is shown in Table 1-18 by year type.

**Table 1-18. Total Historical Delta Inflow by Year Type**

| Year Type | Average Monthly Release (cfs) | | | | | | | | | | | | Annual Total (TAF) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Oct | Nov | Dec | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | |
| All Years | 14,175 | 14,393 | 27,607 | 58,848 | 65,903 | 59,310 | 41,364 | 34,635 | 27,197 | 23,377 | 20,039 | 18,417 | 24,456 |
| Wet | 17,008 | 17,478 | 44,745 | 115,602 | 121,007 | 106,529 | 80,054 | 60,166 | 42,826 | 31,164 | 24,795 | 23,444 | 41,303 |
| Above Normal | 12,464 | 13,032 | 21,753 | 49,529 | 58,561 | 58,862 | 36,989 | 39,892 | 30,631 | 24,398 | 22,061 | 19,005 | 23,377 |
| Below Normal | 13,054 | 12,937 | 22,028 | 37,391 | 55,617 | 46,451 | 26,900 | 20,893 | 22,358 | 21,709 | 19,333 | 17,725 | 19,075 |
| Dry | 12,772 | 13,959 | 19,683 | 24,207 | 24,168 | 25,838 | 16,975 | 16,017 | 15,091 | 19,875 | 17,436 | 14,929 | 13,369 |
| Critical | 13,411 | 11,589 | 15,418 | 18,260 | 27,989 | 18,667 | 11,977 | 10,553 | 10,729 | 12,223 | 11,771 | 12,695 | 10,573 |

*Source: Interagency Ecological Program Dayflow Calculation (2011)*

Notes:
Period of record WY 1992–2010
Year types as defined in the Sacramento Valley Water Year Hydrologic Classification Index
Key:
cfs = cubic feet per second
TAF = thousand acre-feet
WY = water year

*Delta Exports* The Jones Pumping Plant consists of six pumps, with a maximum export capacity of 4,600 cfs. The Jones Pumping Plant is at the end of an earth-lined intake channel about 2.5 miles long. Table 1-19 shows the respective historical average monthly pumping volumes for the Jones Pumping Plant by year type.

**Table 1-19. Historical Exports from the C.W. "Bill" Jones Pumping Plant by Year Type**

| Year Type | Average Monthly Release (cfs) | | | | | | | | | | | | Annual Total (TAF) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Oct | Nov | Dec | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | |
| All Years | 3,774 | 3,539 | 3,202 | 3,505 | 3,512 | 3,176 | 2,014 | 1,409 | 2,893 | 3,967 | 4,010 | 4,083 | 2,364 |
| Wet | 3,965 | 3,575 | 3,377 | 3,545 | 3,325 | 2,797 | 2,067 | 2,104 | 3,746 | 4,365 | 4,391 | 4,335 | 2,517 |
| Above Normal | 3,413 | 3,357 | 2,721 | 3,921 | 4,072 | 3,796 | 2,276 | 1,330 | 3,402 | 4,297 | 4,364 | 4,313 | 2,494 |
| Below Normal | 4,296 | 4,316 | 4,142 | 4,350 | 3,961 | 4,133 | 1,952 | 960 | 3,625 | 4,367 | 4,422 | 4,385 | 2,717 |
| Dry | 3,914 | 3,906 | 3,790 | 3,438 | 3,558 | 3,029 | 2,159 | 856 | 2,764 | 4,241 | 4,230 | 4,176 | 2,423 |
| Critical | 3,023 | 3,124 | 2,999 | 2,736 | 3,166 | 3,180 | 1,638 | 984 | 1,059 | 1,705 | 1,714 | 2,567 | 1,686 |

*Source: USGS Gaging Station 11313000*

Notes:
Period of record WY 1992–2009
Year types as defined in the Sacramento Valley Water Year Hydrologic Classification Index
Key:
cfs = cubic feet per second
TAF = thousand acre-feet
USGS = U.S. Geological Survey
WY = water year

The SWP Banks Pumping Plant supplies water for the South Bay Aqueduct (SBA) and the California Aqueduct, with an installed capacity of 10,300 cfs. Under current operational constraints, exports from Banks Pumping Plant are generally limited to a daily average of 6,680 cfs, except between December 15 and March 15, when exports can be increased by 33 percent of San Joaquin River flow. The Banks Pumping Plant exports water from Clifton Court Forebay, a 31,000 acre-foot reservoir that provides storage for off-peak pumping, and moderates the effect of the pumps on the fluctuation of flow and stage in adjacent Delta channels. Table 1-20 shows the historical monthly average exports for the Banks Pumping Plant by year type.

**Table 1-20. Historical Exports from the Harvey O. Banks Pumping Plant by Year Type**

| Year Type | Average Monthly Release (cfs) | | | | | | | | | | | | Annual Total (TAF) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Oct | Nov | Dec | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | |
| All Years | 3,781 | 3,699 | 4,164 | 4,395 | 3,731 | 3,353 | 1,816 | 1,098 | 2,485 | 5,309 | 5,501 | 4,975 | 3,699 |
| Wet | 4,586 | 3,975 | 3,827 | 3,535 | 2,620 | 1,991 | 1,595 | 1,481 | 2,929 | 5,554 | 5,568 | 5,423 | 3,975 |
| Above Normal | 3,147 | 4,069 | 4,038 | 6,650 | 6,269 | 5,151 | 3,179 | 1,335 | 5,201 | 6,535 | 6,675 | 6,799 | 4,069 |
| Below Normal | 2,500 | 2,612 | 3,775 | 5,425 | 4,696 | 5,275 | 1,451 | 819 | 2,450 | 5,717 | 6,632 | 5,694 | 2,612 |
| Dry | 3,158 | 4,025 | 4,651 | 4,090 | 3,533 | 3,887 | 1,828 | 666 | 775 | 5,539 | 5,403 | 3,880 | 4,025 |
| Critical | 4,845 | 2,747 | 4,779 | 3,176 | 2,692 | 1,755 | 772 | 736 | 533 | 1,868 | 2,603 | 2,366 | 2,747 |

*Source: DWR CDEC Gage HRO (2011)*

Notes:
Period of record WY 1994–2010
Year types as defined in the Sacramento Valley Water Year Hydrologic Classification Index
Key:
cfs = cubic feet per second
CDEC = California Data Exchange Center
DWR = California Department of Water Resources
TAF = thousand acre-feet
WY = water year

Contra Costa Water District (CCWD) supplies CVP water to its users via a pumping plant at the end of Rock Slough. At Rock Slough, the water is lifted 127 feet into the Contra Costa Canal by a series of four pumping plants. The 47.5-mile-long canal terminates in Martinez Reservoir. The Rock Slough diversion capacity of 350 cfs gradually decreases to 22 cfs at the terminus. CCWD also constructed and operates the 100,000 acre-foot Los Vaqueros Reservoir, which has an intake and pumping plant on the Old River for diverting surplus Delta flows to reservoir storage or contract water to CCWD users. Los Vaqueros is refilled by diversions only when source water chloride concentration is relatively low. Los Vaqueros water is used for water quality blending and delivery during low Delta outflow periods, when the chloride concentration at Rock Slough and Old River is greater than 65 milligrams per liter (mg/L). The Old River facility allows CCWD to divert up to 250 cfs to a blending facility with the Contra Costa Canal, and to divert up to 200 cfs of CVP and Los Vaqueros water rights water for storage in Los Vaqueros

Reservoir. CCWD also has a third diversion facility in the Delta at the southern end of a 3,000-foot-long channel running due south of Suisun Bay, near Mallard Slough, with a capacity of 39.3 cfs, but the Mallard Slough facility is only used during periods of very high Delta outflow. Table 1-21 shows the historical monthly average exports for the CCWD Rock Slough Pumping Plant by year type.

**Table 1-21. Historical Exports from the Contra Costa Water District Rock Slough Pumping Plant by Year Type**

| Year Type | Average Monthly Release (cfs) | | | | | | | | | | | | Annual Total (TAF) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Oct | Nov | Dec | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | |
| All Years | 198 | 165 | 126 | 110 | 108 | 104 | 114 | 149 | 140 | 210 | 205 | 205 | 111 |
| Wet | 223 | 186 | 117 | 104 | 76 | 72 | 80 | 122 | 137 | 190 | 222 | 226 | 106 |
| Above Normal | 115 | 152 | 145 | 123 | 186 | 175 | 186 | 229 | 152 | 281 | 240 | 228 | 134 |
| Below Normal | **No Below Normal Years in Period of Record** | | | | | | | | | | | | |
| Dry | 218 | 54 | 35 | 13 | 16 | 16 | 31 | 69 | 47 | 168 | 29 | 32 | 44 |
| Critical | 211 | 179 | 173 | 159 | 155 | 155 | 168 | 176 | 181 | 208 | 213 | 214 | 133 |

*Source: USGS Gaging Station 11337000*

Notes:
Period of record WY 1992–2001
Year types as defined in the Sacramento Valley Water Year Hydrologic Classification Index
Key:
cfs = cubic feet per second
TAF = thousand acre-feet
USGS = U.S. Geological Survey
WY = water year

*Delta Outflow* Because tidal inflows are approximately equivalent to tidal outflows during each daily tidal cycle, tributary inflows and export pumping are the principal variables that define the range of hydrodynamic conditions in the Delta. Excess outflow occurs almost entirely during the winter and spring months. Average winter outflow is about 32,000 cfs, while the average summer outflow is 6,000 cfs. Due to tidal factors and changing channel geometry, Delta outflow is typically a calculated value rather than a directly measured one. Table 1-22 shows the historical average calculated Delta outflow by year type.

**Table 1-22. Calculated Historical Delta Outflow by Year Type**

| Year Type | Average Monthly Release (cfs) | | | | | | | | | | | | Annual Total (TAF) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Oct | Nov | Dec | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | |
| All Years | 5,424 | 14,518 | 30,768 | 52,981 | 62,052 | 53,002 | 37,108 | 26,492 | 15,823 | 8,322 | 6,569 | 9,171 | 19,662 |
| Wet | 6,867 | 9,969 | 38,735 | 111,298 | 117,230 | 103,527 | 75,658 | 54,680 | 32,121 | 16,432 | 10,641 | 10,715 | 35,427 |
| Above Normal | 5,325 | 6,242 | 15,851 | 41,114 | 50,914 | 51,526 | 30,858 | 35,013 | 18,864 | 9,395 | 6,977 | 5,068 | 16,718 |
| Below Normal | 5,462 | 5,913 | 15,347 | 29,704 | 49,137 | 36,968 | 23,579 | 16,652 | 11,085 | 7,009 | 4,603 | 5,280 | 12,672 |
| Dry | 4,241 | 5,916 | 11,722 | 17,074 | 18,830 | 18,455 | 11,807 | 12,051 | 7,644 | 5,203 | 3,714 | 4,175 | 7,296 |
| Critical | 4,225 | 5,193 | 8,854 | 13,916 | 24,473 | 12,020 | 7,963 | 6,450 | 4,821 | 3,697 | 3,063 | 4,300 | 5,945 |

*Source: Interagency Ecological Program Dayflow Calculation (2011)*

Notes:
Period of record WY 1992–2010
Year types as defined in the Sacramento Valley Water Year Hydrologic Classification Index
Key:
cfs = cubic feet per second
TAF = thousand acre-feet
WY = water year

### *CVP/SWP Service Areas*

This section describes the hydrology and hydraulics of the CVP/SWP service areas south of the primary study area.

**CVP Service Areas** Downstream from the Jones Pumping Plant, CVP water flows in the Delta-Mendota Canal and can be pumped into the California Aqueduct through the Intertie, diverted by the O'Neill Pumping-Generating Plant into the O'Neill Forebay, or can continue down the Delta-Mendota Canal for delivery to CVP contractors.

The Intertie is located in an unincorporated area of the San Joaquin Valley in Alameda County, west of Tracy, California. The Intertie, a shared Federal-State water system feature, connects the Delta-Mendota Canal and the California Aqueduct via two 500 linear foot long, 108-inch-diameter pipes. A pump station with pumping capacity of 467 cfs lifts water from the Delta-Mendota Canal into the California Aqueduct through about 50 feet of head. The Intertie addresses Delta-Mendota Canal conveyance conditions that had restricted use of the Jones Pumping Plant to less than its design capacity (4,600 cfs), potentially restoring as much as 35,000,000 acre-feet of average annual deliveries to the CVP. The Intertie provides redundancy in the water distribution system, allows for maintenance and repair activities that are less disruptive to water deliveries, and provides the flexibility to respond to CVP and SWP emergencies.

The O'Neill Pumping-Generating Plant releases flows from the O'Neill Forebay back to the Delta-Mendota Canal. The O'Neill Pumping-Generating Plant consists of six pump-generating units, with a capacity of 700 cfs each.

The O'Neill Forebay is a joint CVP/SWP facility, with a storage capacity of about 56 MAF. In addition to its interactions with the Delta-Mendota Canal via

the O'Neill Pumping-Generating Plant, it is a part of the SWP California Aqueduct. The O'Neill Forebay serves as a regulatory body for San Luis Reservoir; the William R. Gianelli (Gianelli) Pumping-Generating Plant, also a joint CVP/SWP facility, can pump flows from the O'Neill Forebay into San Luis Reservoir, and also make releases from San Luis Reservoir to the O'Neill Forebay for diversion to either the Delta-Mendota Canal or the California Aqueduct. Also, several water districts receive diversions directly from the O'Neill Forebay. The Gianelli Pumping-Generating Plant consists of eight units, with 1,375 cfs of capacity each.

San Luis Reservoir lies at the base of foothills on the west side of the San Joaquin Valley. The reservoir provides offstream storage for excess winter and spring flows diverted from the Delta. It is sized to provide seasonal carryover storage, with a total capacity of 2,027,840 acre-feet. The CVP share of the storage is 965,660 acre-feet; the remaining 1,062,180 acre-feet are the SWP share. During spring and summer, water demands and schedules are greater than the capability of Reclamation and the California Department of Water Resources (DWR) to pump water from the Jones and Banks pumping plants; water stored in San Luis Reservoir is used to make up the difference. Since San Luis Reservoir receives very little natural inflow, water must be stored during the fall and winter when the two Delta pumping plants can pump more water from the Delta than is needed to meet water demands. The CVP share of San Luis Reservoir is typically at its lowest in August and September, and at its maximum in April. Table 1-23 shows historical monthly average storage in the CVP share of San Luis Reservoir by year type.

The San Felipe Division of the CVP supplies water to customers in Santa Clara and San Benito counties from San Luis Reservoir. The operation of San Luis Reservoir has the potential to affect the water quality and reliability of these supplies if reservoir storage drops below 300,000 acre-feet.

**Table 1-23. Historical End-of-Month CVP San Luis Storage by Year Type**

| Year Type | Average End-of-Month Storage (TAF) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Oct | Nov | Dec | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep |
| All Years | 372 | 509 | 633 | 767 | 836 | 892 | 846 | 679 | 493 | 297 | 209 | 270 |
| Wet | 442 | 573 | 703 | 827 | 900 | 942 | 915 | 798 | 635 | 419 | 295 | 329 |
| Above Normal | 241 | 374 | 478 | 662 | 796 | 932 | 917 | 767 | 690 | 420 | 312 | 376 |
| Below Normal | 355 | 509 | 701 | 855 | 907 | 951 | 830 | 540 | 285 | 123 | 90 | 157 |
| Dry | 492 | 652 | 793 | 904 | 896 | 899 | 828 | 587 | 317 | 204 | 172 | 268 |
| Critical | 404 | 549 | 662 | 770 | 829 | 926 | 879 | 742 | 461 | 178 | 31 | 94 |

*Source: DWR CDEC Gage SLF (2011)*

Notes:
Period of record WY 1992–2009
Year types as defined in the Sacramento Valley Water Year Hydrologic Classification Index
Key:
CDEC = California Data Exchange Center
DWR = California Department of Water Resources
TAF = thousand acre-feet
WY = water year

South of the O'Neill Forebay, the Delta-Mendota Canal terminates in the Mendota Pool, about 30 miles west of Fresno. From the Delta-Mendota Canal, the CVP makes diversions to multiple water users and refuges. The Delta-Mendota Canal capacity at the terminus is 3,211 cfs. Parallel to the Delta-Mendota Canal, the San Luis Canal-California Aqueduct is a joint-use facility for the CVP and SWP. It begins on the southeastern edge of the O'Neill Forebay and extends about 101.5 miles southeasterly to a point near Kettlemen City. Water from the canal serves the San Luis Federal service area, mostly for agricultural purposes and for some M&I uses. The canal has a capacity ranging from 8,350 cfs to 13,100 cfs.

**SWP Service Areas** South of the Banks Pumping Plant, the California Aqueduct flows into Bethany Reservoir, a 5,000 acre-foot forebay for the South Bay Pumping Plant.

Downstream from Bethany Reservoir the Intertie, a shared Federal-State water system feature, connects the California Aqueduct and the Delta-Mendota Canal via two 500-linear-foot-long, 108-inch-diameter pipes. The Intertie allows for a gravity diversion of 900 cfs from the California Aqueduct to the 50-foot-lower Delta-Mendota Canal. The Intertie provides redundancy in the water distribution system, allows for maintenance and repair activities that are less disruptive to water deliveries, and provides the flexibility to respond to CVP and SWP emergencies.

Below the Intertie, the California Aqueduct flows through a series of checks to the aforementioned O'Neill Forebay, and is either pumped into San Luis Reservoir or released to the San Luis Canal, the CVP/SWP joint-use portion of

the California Aqueduct. Table 1-24 shows the historical monthly average storage in the SWP share of San Luis Reservoir by year type. Deliveries are made from the California Aqueduct to agricultural and M&I contractors.

**Table 1-24. Historical End-of-Month SWP San Luis Storage by Year Type**

| Year Type | Average End-of-Month Storage (TAF) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Oct | Nov | Dec | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep |
| All Years | 595 | 639 | 725 | 876 | 968 | 1,008 | 943 | 797 | 643 | 567 | 534 | 583 |
| Wet | 822 | 907 | 988 | 1,097 | 1,110 | 1,084 | 1,023 | 926 | 824 | 770 | 700 | 781 |
| Above Normal | 410 | 451 | 523 | 824 | 996 | 1,021 | 966 | 797 | 672 | 605 | 611 | 727 |
| Below Normal | 607 | 613 | 616 | 809 | 972 | 1,069 | 939 | 674 | 435 | 370 | 409 | 514 |
| Dry | 600 | 653 | 800 | 878 | 977 | 1,034 | 945 | 719 | 489 | 426 | 455 | 452 |
| Critical | 763 | 679 | 736 | 799 | 883 | 1,023 | 944 | 829 | 608 | 404 | 325 | 390 |

*Source: DWR CDEC Gage LUS (2011)*

Notes:
Period of record WY 1992–2010
Year types as defined in the Sacramento Valley Water Year Hydrologic Classification Index
Key:
CDEC = California Data Exchange Center
DWR = California Department of Water Resources
TAF = thousand acre-feet
WY = water year

### 1.1.3 Surface Water Supply

While water supply reliability is one of the two primary planning objectives of the SLWRI, operations for Shasta Reservoir are primarily focused on delivering water supply to CVP contractors. However, because of the interconnectivity of the CVP and SWP, water supply operations of the SWP could be affected by changes in operations of the CVP associated with the SLWRI.

#### *CVP/SWP Service Areas*

This section describes surface water supply to CVP and SWP contractors.

**CVP Contractors** At certain times of the year, operations of Shasta Reservoir are driven by water supply needs of the CVP Contractors. The CVP has 273 water service contractors. The CVP provides water to Settlement contractors in the Sacramento Valley, exchange contractors in the San Joaquin Valley, agricultural and M&I water service contractors in both the Sacramento and San Joaquin valleys, and wildlife refuges both north and south of the Delta. At the beginning of each year, Reclamation evaluates hydrologic conditions throughout California and uses this information to forecast CVP operations, and to estimate the amount of water to be made available to the Federal water service contractors for the year (allocations to Settlement and exchange contractors are fixed according to unimpaired inflow to Shasta Reservoir).

The majority of the Federal water service contractors have service areas located south of the Delta. Most of their supplies must be conveyed through the Delta before delivery. Allocations vary considerably from year to year. In general, allocations to CVP water service contractors south of the Delta are lower than allocations to service contractors in the Sacramento Valley. A detailed summary of CVP annual contract amounts for service areas supplied from the Delta is presented in Table 1-25.

**Table 1-25. Summary of CVP Contract Amounts for Service Areas South of the Delta**

| Contractors | CVP Long-Term Contracts | | | | | Water Right, Annual Amount (acre-feet) |
|---|---|---|---|---|---|---|
| | Contract Number | Current Effective Periods | Annual Entitlements (acre-feet) | | Types | |
| **DELTA-MENDOTA CANAL** | | | | | | |
| **Exchange Contractors** | I1r-1144 | - | **840,000** | | | |
| Central California Irrigation District, Columbia Canal Co., Firebaugh Canal Water District, San Luis Canal Co. | | | | | Exchange | |
| **Refuges** | | | **177,407** | | | |
| Grassland Water District | 01-WC-20-1754 | 03/01/2001 – 02/28/2026 | 125,000 | 1 | Refuge | - |
| California Department of Fish and Game (total) | 01-WC-20-1756 | 03/01/2001 – 02/28/2026 | 37,117 | 1 | Refuge | - |
| Volta Wildlife Management Area | 01-WC-20-1756 | 03/01/2001 – 02/28/2026 | 13,000 | 1 | Refuge | - |
| Los Banos Wildlife Management Area | 01-WC-20-1756 | 03/01/2001 – 02/28/2026 | 10,470 | 1 | Refuge | - |
| Salt Slough | 01-WC-20-1756 | 03/01/2001 – 02/28/2026 | 6,680 | 1 | Refuge | - |
| China Island | 01-WC-20-1756 | 03/01/2001 – 02/28/2026 | 6,967 | 1 | Refuge | - |
| National Wildlife Refuge in San Joaquin Valley | 01-WC-20-1758 | 03/01/2001 – 02/28/2026 | 15,290 | 1 | Refuge | - |
| Kesterson National Wildlife Refuge | 01-WC-20-1758 | 03/01/2001 – 02/28/2026 | 10,000 | 1 | Refuge | - |
| Freitas | 01-WC-20-1758 | 03/01/2001 – 02/28/2026 | 5,290 | 1 | Refuge | - |
| **Irrigation and M&I** | | | **361,872** | | | |
| City of Tracy | 14-06-200-7858A-IR1 (interim) | 01/01/2014 – 02/29/2016 | 20,000 | | M&I | - |
| Banta-Carbona Irrigation District | 14-06-200-4305A-LTR1 | 03/01/2005 – 02/28/2030 | 20,000 | | Irrigation and M&I | - |
| West Side Irrigation District | 7-07-20-W0045-LTR1 | 03/01/2005 – 02/28/2030 | 5,000 | | Irrigation and M&I | - |
| Del Puerto Water District | 14-06-200-922-LTR1 | 03/01/2005 – 02/28/2030 | 140,210 | 5 | Irrigation and M&I | - |
| West Stanislaus Irrigation District | 14-06-200-1072-LTR1 | 03/01/2005 – 02/28/2030 | 50,000 | | Irrigation and M&I | - |
| Patterson Irrigation District | 14-06-200-3598A-LTR1 | 03/01/2005 – 02/28/2030 | 16,500 | | Irrigation and M&I | 6,000 |
| Centinella Water District | 7-07-20-W0055-LTR1 | 03/01/2005 – 02/28/2030 | 2,500 | | Irrigation and M&I | - |
| Broadview Water District | 14-06-200-8092-LTR1 | 03/01/2005 – 02/28/2030 | 27,000 | | Irrigation and M&I | - |
| Byron Bethany Irrigation District | 14-06-200-785-LTR1 | 03/01/2005 – 02/28/2030 | 20,600 | | Irrigation and M&I | - |
| Eagle Field Water District | 14-06-200-7754-LTR1 | 03/01/2005 – 02/28/2030 | 4,550 | | Irrigation and M&I | - |
| Mercy Springs Water District | 14-06-200-3365A-LTR1 | 03/01/2005 – 02/28/2030 | 2,842 | | Irrigation and M&I | - |
| Oro Loma Water District | 14-06-200-7823-LTR1 | 03/01/2005 – 02/28/2030 | 4,600 | | Irrigation and M&I | - |
| DWR Intertie @MP7.70-R | NA | NA | NA | | Irrigation and M&I | - |
| Newman Wasteway Recirculation | NA | NA | NA | | Irrigation and M&I | - |
| Panoche Water District | NA | NA | NA | | Irrigation and M&I | - |
| San Luis Water District | 14-06-200-7773A-LTR1 | 03/01/2005 – 02/28/2030 | 45,080 | | Irrigation and M&I | - |
| Widren Water District | 14-06-200-8018-LTR1 | 03/01/2005 – 02/28/2030 | 2,990 | | Irrigation and M&I | - |
| **Total for Delta-Mendota Canal** | | | **1,379,279** | | | 6,000 |

**Table 1-25. Summary of CVP Contract Amounts for Service Areas South of the Delta (contd.)**

| Contractors | CVP Long-Term Contracts | | | | | Water Right, Annual Amount (acre-feet) |
|---|---|---|---|---|---|---|
| | Contract Number | Current Effective Periods | Annual Entitlements (acre-feet) | | Types | |
| **SAN JOAQUIN AND MENDOTA POOL** | | | | | | |
| **Exchange Contractors** | I1r-1144 | | **840,000** | | Exchange | - |
| Central California Irrigation District, Columbia Canal Co., Firebaugh Canal Water District, San Luis Canal Co. | | | | | Exchange | |
| **Refuges** | | | **218,208** | | | |
| Grassland Water District | 01-WC-20-1754 | 03/01/2001 – 02/28/2026 | 125,000 | [1] | Refuge | - |
| California Department of Fish and Game | 01-WC-20-1756 | 03/01/2001 – 02/28/2026 | 51,711 | [1] | Refuge | - |
| Los Banos Wildlife Management Area | 01-WC-20-1756 | 03/01/2001 – 02/28/2026 | 10,470 | [1] | Refuge | - |
| Salt Slough | 01-WC-20-1756 | 03/01/2001 – 02/28/2026 | 6,680 | [1] | Refuge | - |
| China Island | 01-WC-20-1756 | 03/01/2001 – 02/28/2026 | 6,967 | [1] | Refuge | - |
| Mendota Wildlife Management Area | 01-WC-20-1756 | 03/01/2001 – 02/28/2026 | 27,594 | [1] | Refuge | - |
| National Wildlife Refuge in San Joaquin Valley | 01-WC-20-1758 | 03/01/2001 – 02/28/2026 | 41,497 | [1] | Refuge | - |
| San Luis National Wildlife Refuge | 01-WC-20-1758 | 03/01/2001 – 02/28/2026 | 19,000 | [1] | Refuge | - |
| Kesterson National Wildlife Refuge | 01-WC-20-1758 | 03/01/2001 – 02/28/2026 | 10,000 | [1] | Refuge | - |
| West Bear Creek | 01-WC-20-1758 | 03/01/2001 – 02/28/2026 | 7,207 | [1] | Refuge | - |
| Freitas | 01-WC-20-1758 | 03/01/2001 – 02/28/2026 | 5,290 | [1] | Refuge | - |
| **Irrigation and M&I** | | | **106,278** | | | |
| Fresno Slough Water District | 14-06-200-4019A-LTR1 | 03/01/2005 – 02/28/2030 | 4,000 | | Irrigation and M&I | 866 |
| James Irrigation District | 14-06-200-700-A-LTR1 | 03/01/2005 – 02/28/2030 | 35,300 | | Irrigation and M&I | 9,700 |
| Tranquility Irrigation District | 14-06-200-701-A-LTR1 | 03/01/2005 – 02/28/2030 | 13,800 | | Irrigation and M&I | 20,200 |
| Hughes | NA | NA | NA | [3] | Irrigation and M&I | - |
| Reclamation District 1606 | 14-06-200-3802A-LTR1 | 03/01/2005 – 02/28/2030 | 228 | | Irrigation and M&I | 342 |
| Dudley and Indart[4] | NA | NA | NA | | Irrigation and M&I | 2,280 |
| Meyers, Marvin, Patricia [4] | NA | NA | NA | | Irrigation and M&I | 210 |
| Laguna Water District | 2-07-20-W0266-LTR1 | 03/01/2005 – 02/28/2030 | 800 | | Irrigation and M&I | - |
| Tranquility Public Utilities District | 14-06-200-3537A-LTR1 | 03/01/2005 – 02/28/2030 | 70 | | Irrigation and M&I | 93 |
| Mid-Valley Water District (no contract) | NA | NA | NA | | Irrigation and M&I | - |
| Terra Linda Farms (Coelho Family Trust) | 14-06-200-7859A-LTR1 | 03/01/2005 – 02/28/2030 | 2,080 | | Irrigation and M&I | - |
| Westlands Water District | NA | NA | 50,000 | | Irrigation | - |
| Wilson, JW (no contract) | NA | NA | NA | | Irrigation and M&I | - |
| **Total San Joaquin and Mendota Pool** | | | **1,164,486** | | | 33,691 |

**Table 1-25. Summary of CVP Contract Amounts for Service Areas South of the Delta (contd.)**

| Contractors | CVP Long-Term Contracts | | | | | Water Right, Annual Amount (acre-feet) |
|---|---|---|---|---|---|---|
| | Contract Number | | Annual Entitlements | | | |
| **SAN LUIS CANAL / CROSS VALLEY CANAL** | | | | | | |
| **Refuges** | | | **64,711** | | | |
| California Department of Fish and Game | 01-WC-20-1756 | 03/01/2001 – 02/28/2026 | 64,711 | [1] | Refuge | - |
| O'Neill Forebay Wildlife Refuge | NA | NA | NA | | Refuge | - |
| **Irrigation and M&I** | | | **1,703,030** | | | |
| Broadview Water District | 14-06-200-8092-LTR1 | 03/01/2005 – 02/28/2030 | 27,000 | | Irrigation and M&I | - |
| San Luis Water District | 14-06-200-7773A-LTR1 | 03/01/2005 – 02/28/2030 | 80,000 | | Irrigation and M&I | - |
| Veterans Affairs Cemetery | 3-07-20-W1124-LTR1 | 03/01/2005 – 02/28/2045 | 850 | | M&I | - |
| Panoche Water District | 14-06-200-7864A-LTR1 | 03/01/2005 – 02/28/2030 | 94,000 | | Irrigation and M&I | - |
| Pacheco Water District | 6-07-20-W0469-LTR1 | 03/01/2005 – 02/28/2030 | 10,080 | | Irrigation and M&I | 6,000 |
| City of Avenal | 14-06-200-4619-LTR1 | 03/01/2005 – 02/28/2045 | 3,500 | | M&I | - |
| City of Coalinga | 14-06-200-4173A-LTR1 | 03/01/2005 – 02/28/2045 | 10,000 | | M&I | - |
| City of Huron | 14-06-200-7081A-LTR1 | 03/01/2005 – 02/28/2045 | 3,000 | | M&I | - |
| Westlands Water District | 14-06-200-495A-LTR1 | 03/01/2005 – 02/28/2030 | 1,150,000 | | Irrigation and M&I | - |
| County of Fresno | 14-06-200-8292A-LTR1 | 03/01/2005 – 02/28/2030 | 3,000 | | Irrigation and M&I | - |
| Hills Valley Irrigation District | 14-06-200-8466A-LTR1 | 03/01/2005 – 02/28/2030 | 3,346 | | Irrigation and M&I | - |
| Kern-Tulare Irrigation District | 14-06-200-8601A-LTR1 | 03/01/2005 – 02/28/2030 | 40,000 | | Irrigation and M&I | - |
| Lower Tule River Irrigation District | 14-06-200-8237A-LTR1 | 03/01/2005 – 02/28/2030 | 31,102 | | Irrigation and M&I | - |
| Pixley Irrigation District | 14-06-200-8238A-LTR1 | 03/01/2005 – 02/28/2030 | 31,102 | | Irrigation and M&I | - |
| Rag Gulch Water District | 14-06-200-8367A-LTR1 | 03/01/2005 – 02/28/2030 | 13,300 | | Irrigation and M&I | - |
| Tri-Valley Water District | 14-06-200-8565A-LTR1 | 03/01/2005 – 02/28/2030 | 1,142 | | Irrigation and M&I | - |
| County of Tulare | 14-06-200-8293A-LTR1 | 03/01/2005 – 02/28/2030 | 5,308 | | Irrigation and M&I | - |
| San Benito Country Water District | 8-07-20-W0130-LTR1 | 03/01/2001 – 02/28/2027 | 35,550 | [4] | Irrigation | - |
| | | | 8,250 | [4] | M&I | - |
| Santa Clara Valley Water District | 7-07-20-W0023-LTR1 | 03/01/2001 – 02/28/2027 | 33,100 | [4] | Irrigation | - |
| | | | 119,400 | [4] | M&I | - |
| **Total for San Luis and Cross Valley Canals** | | | **1,767,741** | | | 6,000 |
| **Totals for CVP South of Delta** | | | **3,471,506** | | | 45,691 |

*Data Source: CVPIA long-term water service contract Web site (Reclamation 2013); Reclamation 2014*

Notes:
[1] Level 2 contract amount.
[2] Conveyance not available.
[3] CVPIA long-term contract information is not available. Present in historical delivery record.
[4] Interim contract is based on the latest information available from the CVPIA.
[5] Del Puerto contract includes Davis, Hospital, Kern Canon, Salado, Sunflower, Mustang, Orestimba, Foothill, Quinto, and Romero water districts.

Key: - = 0
CVP = Central Valley Project
CVPIA = Central Valley Project Improvement Act
DWR = California Department of Water Resources
M&I = municipal & industrial
NA = Not Available

The CVP water service contracts have varying water shortage provisions. Since 1991, Reclamation has been developing an M&I Water Shortage Policy applicable to all CVP M&I contractors. This policy provides M&I water supplies with a 75 percent water supply reliability based on a contractor's historical use, as defined by the last 3 years of water deliveries unconstrained by the availability of CVP water. Before M&I supplies are reduced, irrigation water supplies would be reduced below 75 percent of contract entitlement. The proposed policy also provides that when the allocation of irrigation water is reduced below 25 percent of contract entitlement, Reclamation will reassess the availability of CVP water and CVP water demand and, because of limited water supplies, M&I water supplies may be reduced below 75 percent of adjusted historical use. Because of water rights secured before construction of the CVP, Sacramento Valley Settlement contractors and San Joaquin Valley exchange contractors have a higher level of reliability for their supplies; except in extremely dry years, when the water year type, as defined by the Shasta Hydrologic Index, is classified as critical, Settlement and exchange contractors receive 100 percent of their contract amounts. In Shasta critical years, Settlement and exchange contractors receive 75 percent of their contract amounts. A Shasta critical year is defined as a year when the total inflow to Shasta Reservoir is below 3.2 MAF, or the average inflow for a 2-year period is below 4.0 MAF and the total 2-year deficiency for deliveries is higher than 0.8 MAF. Table 1-26 shows historical CVP allocations since 1997.

**Table 1-26. Historical CVP Annual Allocations**

| Year | Year Type | CVP Contract Allocation (%) | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | Agricultural | | Urban | | Wildlife Refuges | | Settlement/ Exchange |
| | | North of Delta | South of Delta | North of Delta | South of Delta | North of Delta | South of Delta | |
| 1997 | Wet | 90 | 90 | 90 - 100 | 90 - 100 | As scheduled | As scheduled | 100 |
| 1998 | Wet | 100 | 100 | 100 | 100 | 100 | 100 | 100 |
| 1999 | Wet | 100 | 70 | 95 | 95 | 100 | 100 | 100 |
| 2000 | Above Normal | 100 | 65 | 100 | 90 | 100 | 100 | 100 |
| 2001 | Dry | 60 | 49 | 85 | 77 | 100 | 100 | 100 |
| 2002 | Dry | 100 | 70 | 100 | 95 | 100 | 100 | 100 |
| 2003 | Above Normal | 100 | 75 | 100 | 100 | 100 | 100 | 100 |
| 2004 | Below Normal | 100 | 70 | 100 | 95 | 100 | 100 | 100 |
| 2005 | Above Normal | 100 | 85 | 100 | 100 | 100 | 100 | 100 |
| 2006 | Wet | 100 | 100 | 100 | 100 | 100 | 100 | 100 |
| 2007 | Dry | 100 | 50 | 100 | 75 | 100 | 100 | 100 |
| 2008 | Critical | 40 | 40 | 75 | 75 | 100 | 100 | 100 |
| 2009 | Dry | 40 | 10 | 75 | 60 | 100 | 100 | 100 |

*Source: Central Valley Project Operations Web site (Reclamation 2011)*

Note:
Year types as defined in the Sacramento Valley Water Year Hydrologic Classification Index
Key:
CVP = Central Valley Project
TAF = thousand acre-feet

**SWP Contractors** The CVP and SWP are intrinsically linked through the Delta; shared responsibilities under their respective water rights and coordinated operations agreements mean that a change in flow from one project could result in a flow change from the other. Accordingly, SWP water supply operations are discussed below.

The SWP operates under long-term contracts with public water agencies throughout California. These agencies, in turn, deliver water to wholesalers or retailers, or deliver it directly to agricultural and M&I water users (DWR 1999). The SWP contracts between DWR and individual State water contractors define several classifications of water available for delivery under specific circumstances. All classifications are considered “project water.” Table A is an exhibit to the SWP long-term water supply contracts. Table A amounts are used to define each contractor’s proportion of the available water supply that DWR will allocate and deliver to that contractor. Each year, each contractor may request an amount not to exceed its Table A amount. The Table A amounts are used as a basis for allocations to contractors, but the actual annual supply to contractors is variable and depends on the amount of water that is available. Water delivery capabilities are frequently lower than Table A amounts. Table

A water is water delivered according to this apportionment methodology and is given first priority for delivery (DWR 2005). The total Table A amount has increased since inception of the SWP, and is projected to reach a maximum amount of about 4.2 MAF per year by 2021. The current Table A amount provided each year is about 4.15 MAF (DWR 2006). Maximum annual Table A amounts allocated to the 29 SWP contractors are presented in Table 1-27.

**Table 1-27. Maximum Annual SWP Table A Amounts**

| Contractors | Maximum Table A | |
|---|---|---|
| | (acre-feet) | Percent of Total |
| **Feather River** | | |
| County of Butte | 27,500 | 0.66 |
| Plumas County FC&WCD | 2,700 | 0.06 |
| City of Yuba City | 9,600 | 0.23 |
| **Total for Feather River** | **39,800** | **0.95** |
| **North Bay** | | |
| Napa County FC&WCD | 29,025 | 0.70 |
| Solano County WA | 47,756 | 1.14 |
| **Total for North Bay** | **76,781** | **1.84** |
| **South Bay** | | |
| Alameda County FC&WCD, Zone 7 | 80,619 | 1.93 |
| Alameda County WD | 42,000 | 1.01 |
| Santa Clara Valley WD | 100,000 | 2.40 |
| **Total for South Bay Aqueduct** | **222,619** | **5.34** |
| **San Joaquin Valley** | | |
| Oak Flat WD | 5,700 | 0.14 |
| County of Kings | 9,305 | 0.22 |
| Dudley Ridge WD | 57,343 | 1.37 |
| Empire West Side ID | 3,000 | 0.07 |
| Kern County WA | 998,730 | 23.93 |
| Tulare Lake Basin WSD | 95,922 | 2.30 |
| **Total for San Joaquin Valley** | **1,170,000** | **28.04** |
| **Central Coast** | | |
| San Luis Obispo County FC&WCD | 25,000 | 0.60 |
| Santa Barbara County FC&WCD | 45,486 | 1.09 |
| **Total for Central Coast** | **70,486** | **1.69** |

**Table 1-27. Maximum Annual SWP Table A Amounts (contd.)**

| Contractors | Maximum Table A | |
|---|---|---|
| | (acre-feet) | Percent of Total |
| **Southern California** | | |
| Antelope Valley-East Kern WA | 141,400 | 3.39 |
| Castaic Lake WA | 95,200 | 2.28 |
| Coachella Valley WD | 121,100 | 2.90 |
| Crestline-Lake Arrowhead WA | 5,800 | 0.14 |
| Desert WA | 50,000 | 1.20 |
| Littlerock Creek ID | 2,300 | 0.06 |
| Mojave WA | 75,800 | 1.82 |
| MWDSC | 1,911,500 | 45.81 |
| Palmdale WD | 21,300 | 0.51 |
| San Bernardino Valley MWD | 102,600 | 2.46 |
| San Gabriel Valley MWD | 28,800 | 0.69 |
| San Gorgonio Pass WA | 17,300 | 0.41 |
| Ventura County FCD | 20,000 | 0.48 |
| **Total for Southern California** | **2,593,100** | **62.14** |
| **Table A Total** | ***4,172,786*** | ***100.0*** |

*Source: DWR 2006*

Key:
DWR = California Department of Water Resources
FC&WCD = Flood Control and Water Conservation District
FCD = Flood Control District
ID = Irrigation District
MWD = Municipal Water District
MWDSC = Metropolitan Water District of Southern California
SWP = State Water Project
WA = Water Agency
WD = Water District
WSD = Water Storage District

The Monterey Agreement (DWR 2003a), signed by 27 of the 29 SWP water contractors in 1995, restructured the SWP contracts to allocate water based on contractual Table A amounts instead of the amount of water requested for a given year. In times of shortages, the water supply to SWP agricultural and M&I contractors will be reduced equally.

Many contractors also make frequent use of additional contract water types to increase or decrease the amount of water available to the contractors under Table A. Other contract types of water include Article 21 Water, turnback pool water, and carryover water.

The SWP allocation (proportion of Table A to be delivered) for any specific year is made based on a number of factors, including existing storage, current regulatory constraints, projected hydrologic conditions, and desired carryover storage. Since 1995, annual delivery of Table A water has varied between 1.374 MAF (in 2001) and 2.965 MAF (in 2003). Article 21 deliveries have varied between approximately 20,000 acre-feet (in 1998) to 309,000 acre-feet

(in 2000) (DWR 2006). Table 1-28 shows historical SWP deliveries since 1997 by year.

**Table 1-28. Historical Annual SWP Deliveries**

| Year | Year Type | Table A | | Article 21 (TAF) | Fish and Wildlife (TAF) | Water Rights and Other Contractors (TAF) |
|---|---|---|---|---|---|---|
| | | Allocation (%) | Delivery (TAF) | | | |
| 1997 | Wet | - | 2,324 | 21 | 1315 | 4.15 |
| 1998 | Wet | 100 | 1,726 | 20 | 2187 | 2.11 |
| 1999 | Wet | 100 | 2,379 | 158 | 7794 | 4.32 |
| 2000 | Above Normal | 90 | 3,201 | 309 | 1419 | 4.03 |
| 2001 | Dry | 39 | 1,547 | 43 | 1614 | 2.93 |
| 2002 | Dry | 70 | 2,573 | 43 | 1442 | 3.69 |
| 2003 | Above Normal | 90 | 2,901 | 60 | 1260 | 2.85 |
| 2004 | Below Normal | 65 | 2,600 | 218 | 1533 | 2.87 |
| 2005 | Above Normal | 90 | - | - | - | - |
| 2006 | Wet | 100 | - | - | - | - |
| 2007 | Dry | 60 | - | - | - | - |

*Source: DWR Bulletin 132 1997 through 2006 (DWR 2006)*

Notes:
Year types as defined in the Sacramento Valley Water Year Hydrologic Classification Index
Delivery information for 2005-2007 not available at time of publication
Key:
- = No data available
DWR = California Department of Water Resources
TAF = thousand acre-feet

### 1.1.4 Groundwater Resources

The use and sustainable management of groundwater resources is an important component in meeting water demands in California. This section describes groundwater resources within the boundaries of the primary and extended study areas. Information specific to groundwater resources includes groundwater levels and budget and groundwater quality.

The primary study area includes Shasta Lake and vicinity, and the upper Sacramento River to Red Bluff. The area of analysis for groundwater resources in the primary study area primarily includes the following groundwater basins:

- Redding Groundwater Basin
- Sacramento Groundwater Basin

The Redding Groundwater Basin and Sacramento Groundwater Basin can be further divided into 6 and 18 subbasins, respectively, as delineated in DWR Bulletin 118 (DWR 2003b). Groundwater subbasins in the primary study area are listed in Table A-1, along with a general description of the location and area

of each subbasin, historical groundwater level trends, and groundwater budget, if available. Groundwater quality conditions in the subbasins are summarized in Table 1-29.

The extended study area includes the Sacramento River from Red Bluff to the Delta, as well as CVP/SWP service areas. Groundwater in the extended study area includes supply from the Sacramento Valley Groundwater Basin, San Joaquin Valley, Santa Clara Valley, Antelope Valley, Fremont Valley, Coastal Plain of Los Angeles, and Coastal Plain of Orange County groundwater basins, and multiple other smaller groundwater basins underlying areas that receive water from the CVP/SWP system. These groundwater basins and subbasins are listed and briefly described in Table A-2.

#### *Shasta Lake and Vicinity*

Shasta Lake and vicinity are located in the foothill area northwest of the Redding Groundwater Basin.

**Groundwater Levels and Budget** Small groundwater basins underlying Shasta Lake and vicinity do not have significant groundwater availability for use as a source of supply (Shasta County Water Agency 1998). Groundwater basins underlying Shasta County include the Fall River Valley Groundwater Basin, Lake Britton Groundwater Basin, and North Fork Battle Creek (Table A-1). Of these three groundwater basins, the Fall River Valley Groundwater Basin covers the largest area (54,800 acres) and groundwater extraction for agricultural use in this basin is the highest (approximately 19,000 acre-feet). Estimated groundwater extraction for M&I use in these subbasins ranges from 5 acre-feet to 240 acre-feet. Deep percolation from applied water is minor, ranging from 10 acre-feet to 4,800 acre-feet (Table A-1).

**Groundwater Quality** Groundwater quality in Shasta Lake and vicinity is typically good. Total dissolved solids (TDS) concentrations in the Fall River Valley Groundwater Basin are low, ranging from 115 to 232 mg/L, as presented in Table 1-29.

**Table 1-29. Groundwater Quality Data for the Various Groundwater Basins Throughout California**

| DWR Groundwater Basin/Subbasin Name (number) | TDS (mg/L) | |
|---|---|---|
| | Average | Range |
| Merced Subbasin (5-22.04) | 200–400 | 100–3,600 |
| Delta-Mendota Subbasin (5-22.07) | 770 | 210–86,000 |
| Kings Subbasin (5-22.08) | 200–700 | 40–2,000 |
| Kaweah Subbasin (5-22.11) | 189 | 35–580 |
| Tulare Lake Subbasin (5-22.12) | 200–600 | 200–40,000 |
| Tule Subbasin (5-22.13) | 256 | 200–30,000 |
| Tracy Subbasin (5-22.15) | 1,190 | 210–7,800 |
| Turlock Subbasin (5-22-03) | 200–500 | 100–8,300 |
| Modesto Subbasin (5-22-02) | 60–500 | 200–8,300 |
| Eastern San Joaquin Subbasin (5-22-01) | 310 | 30–1,632 |
| Chowchilla Subbasin (5-22.05) | 200–500 | 120–6,400 |
| Madera Subbasin (5-22.06) | 200–400 | 100–6,400 |
| Westside Subbasin (5-22.09) | 520 | 220–35,000 |
| Kern County Subbasin (5-22.14) | 400–450 | 150–5,000 |
| Pleasant Valley Subbasin (5-22.10) | 1,500 | 1,000–3,000 |
| Antelope Valley Subbasin (6-44) | - | - |
| Fremont Valley Subbasin (6-46) | | |
| Santa Clara Subbasin (2-9.02) | | |
| Central Subbasin (4-11.04) | | |
| Coastal Plain of Orange County (8-1) | | |
| Fall River Valley Groundwater Basin (5-5) | 174 | 115–23 |
| Lake Britton Area Groundwater Basin (5-46) | – | – |
| North Fork Battle Creek Groundwater Subbasin (5-50) | | |
| Enterprise Subbasin (5-6.04) | – | 160–210 |
| Millville Subbasin (5-6.05) | 140 | – |
| Bowman Subbasin (5-6.01) | - | 70–247 |
| Rosewood Subbasin (5-6.02) | - | 118–218 |
| South Battle Creek Subbasin (5-6.06) | 360 | – |
| Red Bluff Subbasin (5-21.50) | 207 | 120–500 |
| Corning Subbasin (5-21.51) | 286 | 130–490 |
| Colusa Subbasin (5-21.52) | 391 | 120–1,220 |
| Bend Subbasin (5-21.53) | – | 334–360 |
| Antelope Subbasin (5-21.54) | 296 | – |
| Dye Creek Subbasin (5-21.55) | 240 | 159-396 |
| Los Molinos Subbasin (5-21.56) | 217 | – |
| Vina Subbasin (5-21.57) | 285 | 48–543 |
| West Butte Subbasin (5-21.58) | 293 | 130-676 |
| North Yuba Subbasin (5-21.60) | – | – |
| South Yuba Subbasin (5-21.61) | – | – |
| Sutter Subbasin (5-21.62) | – | – |
| North American Subbasin (5-21.64) | – | – |
| Solano Subbasin (5-21.66) | 427 | 150–880 |
| Yolo Subbasin (5-21.) | 880 | 480–2,060 |
| Capay Valley Subbasin (5-21.68) | – | – |
| Cosumnes Subbasin (5-22.16) | 218 | 140–438 |
| South American Subbasin (5-21.65) | 221 | 24–581 |

*Source: California's Groundwater Bulletin 118 Update (DWR 2003b)*
Key:
- = no data available
DWR = California Department of Water Resources
mg/L = milligrams per liter
TDS = total dissolved solids

***Upper Sacramento River (Shasta Dam to Red Bluff)***

The upper Sacramento River study area extends from Redding to Red Bluff, and includes the Redding Groundwater Basin and the northern portion of the Sacramento groundwater basin.

The Redding Groundwater Basin underlies most of the upper Sacramento River area between Shasta Dam and Red Bluff. The basin is bordered on the north, east, and west by foothills, and on the south by the Sacramento Valley Groundwater Basin (Tehama GMP 1996). The foothill areas that constitute the eastern and western portions of Shasta and Tehama counties, adjacent to the Redding Groundwater Basin, are designated as "highland" areas, noted for their relative scarcity of groundwater resources. DWR Bulletin 118 (2003b) subdivides the Redding Groundwater Basin into six subbasins: Anderson, Enterprise, Millville, Rosewood, Bowman, and South Battle Creek (see Table A-1).

The Sacramento Groundwater Basin extends from the Redding Groundwater Basin to the San Joaquin Valley, and includes Tehama, Glenn, Butte, Yuba, Colusa, Placer, and Yolo counties. The Sacramento Groundwater Basin is divided into the subbasins that are listed, and briefly described, in Table A-1.

**Groundwater Levels and Budget** In general, groundwater flows southeasterly on the west side of the Redding Groundwater Basin and southwesterly on the east side, toward the Sacramento River (Reclamation and DWR 2003). Historically, groundwater levels in the Redding Groundwater Basin have remained relatively stable, with no apparent long-term trend of declining or increasing levels. A slight decline in groundwater levels associated with the 1976 through 1977 and 1987 through 1994 droughts was followed by a recovery to predrought conditions of the early 1970s and 1980s. Generally, groundwater levels have a seasonal fluctuation of approximately 2 to 15 feet (DWR 2003b). DWR has estimated the total quantity of groundwater storage in the Redding Groundwater Basin at approximately 6.9 MAF (Reclamation and DWR 2003). As of 1995, approximately 12.5 percent of all water used in the Redding Groundwater Basin was derived from groundwater, the vast majority of which was used to meet M&I demands (Shasta County Water Agency 1998). Total annual groundwater pumping for the Redding Groundwater Basin is approximately 37,000 acre-feet (DWR 1998). This is a minor amount compared to the basin's groundwater discharge to surface water of 266,000 acre-feet (Shasta County Water Agency 1998).

In the northern portion of the Sacramento Groundwater Basin, the following three subbasins are included in upper Sacramento River study area: Red Bluff, Antelope, and Bend subbasins (Table A-1). Groundwater extraction in the Red Bluff Subbasin is nearly 90,000 acre-feet. This is much larger than the estimated groundwater pumping of approximately 19,000 acre-feet in the Antelope Subbasin and 340 acre-feet in the Bend subbasin (A-1).

*Groundwater Quality* Groundwater in the Redding area is of good quality, as shown by low TDS concentrations, ranging from 70 to 360 mg/L (Table 1-29). This range is below the California Environmental Protection Agency (Cal/EPA) and U.S. Environmental Protection Agency (EPA) secondary drinking water standard of 500 mg/L and also below the agricultural water quality goal of 450 mg/L. Areas of high salinity and poor quality are generally found on the basin margins where groundwater is derived from marine sedimentary rock (Reclamation and DWR 2003).

Groundwater quality in the Sacramento Groundwater Basin is generally good, and sufficient for agricultural and M&I uses, with TDS levels ranging from 200 to 500 mg/L (DWR 2003b) (Table 1-29). Localized groundwater quality issues occur as a result of natural water quality impairments at the north end of the Sacramento Valley, where marine sedimentary rocks containing brackish to saline water are near the surface (DWR 2003b).

#### *Lower Sacramento River and Delta*

The groundwater basins underlying the lower Sacramento River and Delta areas include the Sacramento Valley Groundwater Basin, and North and South San Joaquin Valley groundwater basins.

**Groundwater Levels and Budget** In the Sacramento Groundwater Basin, groundwater flows inward from the edges of the basin and south parallel to the Sacramento River. Groundwater extraction in some local areas resulted in groundwater depressions and local groundwater gradients (Reclamation and DWR 2003). Before the completion of CVP facilities (1964 through 1971), pumping along the west side of the basin caused groundwater levels to decline. In the Sacramento Groundwater Basin, a slight decline of 2 to 12 feet was experienced in groundwater levels as a result of the 1976 through 1977 and 1987 through 1994 droughts. This was followed by a recovery to predrought conditions of the early 1970s and 1980s. Generally, groundwater-level data show an average seasonal fluctuation ranging from 2 to 15 feet. Groundwater production in the basin increased from 500,000 acre-feet in the 1940s to 2 MAF annually in the mid-1990s.

**Groundwater Quality** As mentioned, groundwater quality in the Sacramento Groundwater Basin is generally good, and sufficient for agricultural and M&I uses, with TDS levels ranging from 200 to 500 mg/L (DWR 2003b) (Table 1-29).

#### *CVP/SWP Service Areas*

The groundwater basins underlying the CVP/SWP service areas include the San Joaquin Valley, Santa Clara Valley, Antelope Valley, Fremont Valley, Coastal Plain of Los Angeles, and Coastal Plain of Orange County groundwater basins, and multiple other smaller groundwater basins underlying areas that receive water from the CVP/SWP system.

**Groundwater Levels and Budget** The San Joaquin Groundwater Basin is a regional basin and is the largest in California, extending approximately from the Delta to Bakersfield. The San Joaquin Valley is divided into nine subbasins, listed in Table A-2 in Exhibit A. Areas within the San Joaquin Groundwater Basin are heavily groundwater-reliant. Groundwater accounts for about 30 percent of the annual supply used for agricultural and urban purposes (DWR 2003b). Groundwater production in the North San Joaquin Groundwater Basin alone increased from 1.5 MAF annually in the 1920s to more than 3.5 MAF annually in 1990 (Reclamation and DWR 2003). In the South San Joaquin Groundwater Basin, groundwater production for agriculture rose from approximately 3.0 MAF per year in the 1920s to more than 5.0 MAF per year 1980s (Reclamation and DWR 2003). Much of the San Joaquin groundwater basin is in overdraft conditions due to extensive groundwater pumping and irrigation, although the extent of overdraft varies widely from region to region.

**Groundwater Quality** Groundwater quality throughout the San Joaquin Valley is in general suitable for most urban and agricultural uses. Average TDS concentrations range from 218 to 1,190 mg/L, as listed in Table 1-29. Areas of high TDS concentration, primarily along the west side of the San Joaquin Valley, are the result of streamflow recharge that originates from marine sediments. High TDS concentrations are also seen in the trough of the Sacramento Valley due to concentration of salts resulting from evaporation and poor drainage (DWR 2003b). Agricultural pesticides and herbicides have been detected in groundwater throughout the region, but primarily along the east side of the San Joaquin Valley, where soil permeability is higher and depth to groundwater is shallower. From 1994 to 2000, 523 public wells out of 689 wells sampled met the State primary maximum contamination levels (MCL) for drinking water. The remaining wells have constituents that exceed one or more MCLs (DWR 2003b).

### 1.1.5 Flood Management

This section describes major features of the flood management system in the primary and extended study areas, including reservoirs, levees, weirs, and bypasses, shown in Figure 1-6. Historical operation of these facilities is also described.

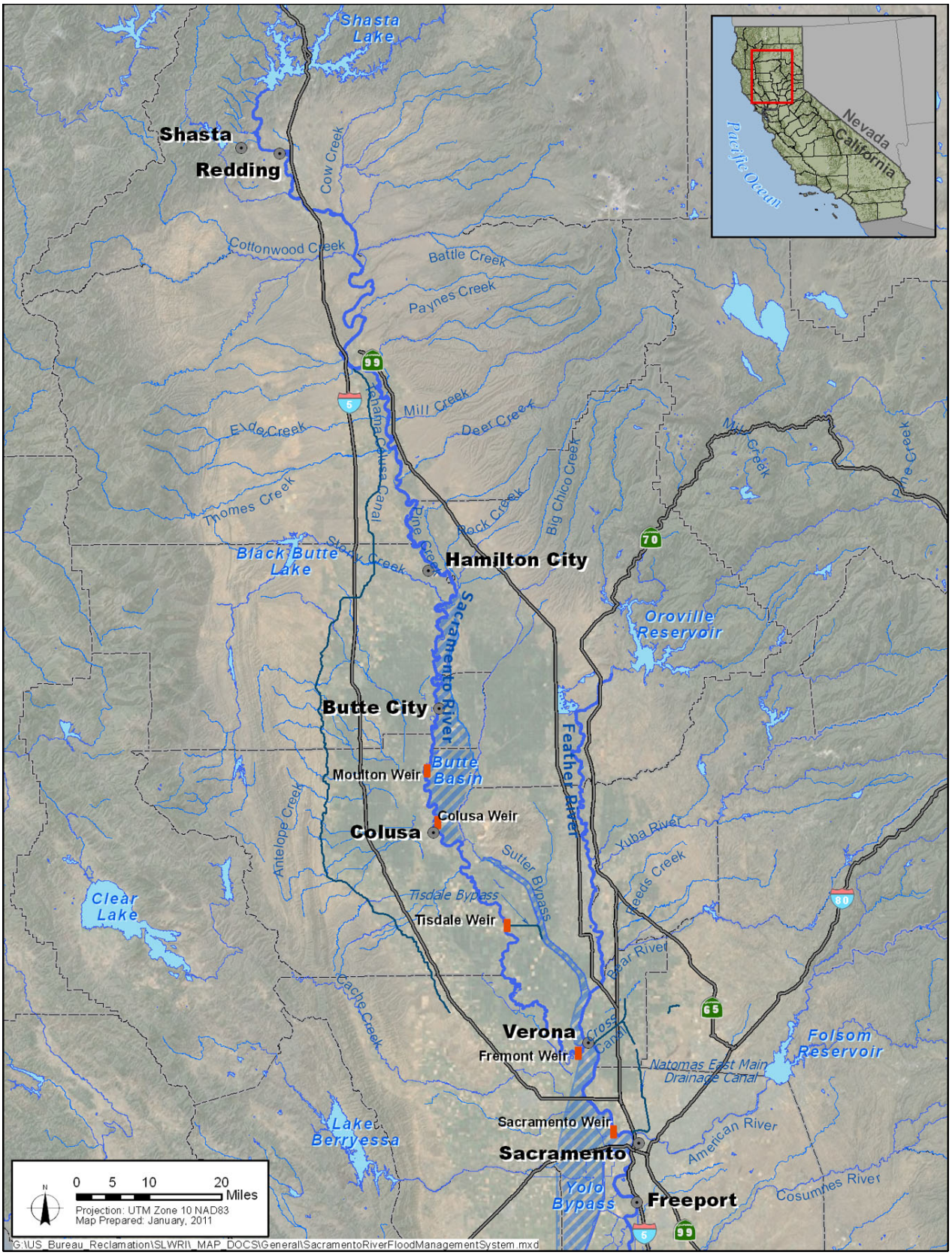


**Figure 1-6. Sacramento Valley Flood Management Facilities**

### *Shasta Lake and Vicinity*

Releases from Shasta Dam are often made for flood management. Table 1-30 shows the historical annual inflow, storage, and outflow for Shasta Reservoir from 1945 through 2013. Releases for flood management either occur in the fall, beginning in early October, to reach the prescribed vacant flood space, or to evacuate space during or after a storm event to maintain the prescribed vacant flood space in the reservoir. During a storm event, releases for flood management occur either over the spillway during large events or through river outlets for smaller events. As shown in Table 1-30, between 1950 and 2013, flows over the spillway occurred in 14 years, or in 20 percent of post 1950 years.

### *Upper Sacramento River*

Historically, the largest flood events along the upper Sacramento River have been from heavy rainfall, with a relatively smaller component of the flows coming from snowmelt in the upper basin. Flood management operations at Shasta Dam include forecasting runoff into Shasta Lake as well as runoff of unregulated creek systems downstream from Keswick Dam. A critical component of upper Sacramento River flood operations is the forecast of local runoff entering the Sacramento River between Keswick Dam and Bend Bridge near Red Bluff.

The unregulated creeks (major tributaries include Cottonwood, Cow, and Battle creeks) discharging into the Sacramento River between Keswick Dam and Bend Bridge can produce high runoff rates into the Sacramento River in short periods of time. During large flood events, the local runoff between Keswick Dam and Bend Bridge can exceed 100,000 cfs.

Regulated peak flood flow frequency curves have been developed at several selected locations within the Sacramento River Basin. The curves were developed to establish the relative frequency of annual peak flows at each location. Earlier curves developed at or near these locations were reevaluated and updated to incorporate recent floods, including floods in 1983, 1986, 1995, and 1997.

## Table 1-30. Historical Shasta Dam and Reservoir Flood Management Operations

| Water Year | Total Inflow (TAF) | End of Sept. Storage (TAF) | Outflows (TAF) | | | | Water Year | Total Inflow (TAF) | End of Sept. Storage (TAF) | Outflows (TAF) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Total | Powerplant | Spillway | Outlets | | | | Total | Powerplant | Spillway | Outlets |
| 1945 | 4,858 | * | 3,462 | 2,624 | 0 | 839 | 1980 | 6,415 | 3321 | 6,139 | 4,773 | 0 | 1,366 |
| 1946 | 5,906 | * | 5,599 | 3,898 | 0 | 1700 | 1981 | 4,103 | 2480 | 4,845 | 4,845 | 0 | 0 |
| 1947 | 3,908 | * | 3,964 | 3,571 | 0 | 393 | 1982 | 9,013 | 3486 | 7,910 | 6,464 | 253 | 1,193 |
| 1948 | 5,416 | * | 4,958 | 4,244 | 0 | 714 | 1983 | 10,794 | 3617 | 10,576 | 7,123 | 1 | 3,452 |
| 1949 | 4,318 | * | 4,303 | 4,303 | 0 | 0 | 1984 | 6,667 | 3240 | 6,944 | 6,514 | 0 | 429 |
| 1950 | 4,133 | * | 3,784 | 3,781 | 1 | 2 | 1985 | 3,971 | 1978 | 5,154 | 5,152 | 2 | 0 |
| 1951 | 6,316 | * | 6,486 | 5,696 | 0 | 790 | 1986 | 7,546 | 3211 | 6,225 | 4,383 | 0 | 1,842 |
| 1952 | 7,785 | * | 6,800 | 5,625 | 9 | 1166 | 1987 | 3,944 | 2108 | 4,957 | 4,800 | 0 | 157 |
| 1953 | 6,540 | 3,300 | 6,408 | 5,067 | 0 | 1341 | 1988 | 3,931 | 1,586 | 4,368 | 3,973 | 0 | 395 |
| 1954 | 6,541 | 3,059 | 6,826 | 5,941 | 0 | 885 | 1989 | 4,745 | 2,096 | 4,154 | 3,951 | 0 | 203 |
| 1955 | 4,112 | 2,455 | 4,612 | 4,612 | 0 | 0 | 1990 | 3,616 | 1,637 | 3,999 | 3,707 | 0 | 292 |
| 1956 | 8,834 | 3,569 | 7,606 | 4,926 | 12 | 2668 | 1991 | 3,051 | 1,340 | 3,286 | 2,666 | 0 | 620 |
| 1957 | 5,368 | 3,485 | 5,341 | 4,841 | 17 | 483 | 1992 | 3,622 | 1,683 | 3,204 | 1,755 | 0 | 1,449 |
| 1958 | 9,698 | 3,473 | 9,610 | 6,672 | 13 | 2,924 | 1993 | 6,825 | 3,102 | 5,316 | 3,728 | 0 | 1,588 |
| 1959 | 5,086 | 2,504 | 5,952 | 5,631 | 0 | 321 | 1994 | 3,087 | 2,102 | 4,002 | 3,252 | 0 | 750 |
| 1960 | 4,733 | 2,756 | 4,380 | 4,380 | 0 | 0 | 1995 | 9,638 | 3,136 | 8,511 | 5,187 | 0 | 3,324 |
| 1961 | 5,071 | 2,333 | 5,402 | 5,402 | 0 | 0 | 1996 | 6,846 | 3,089 | 6,781 | 3,703 | 0 | 3,078 |
| 1962 | 5,262 | 2,908 | 4,582 | 4,582 | 0 | 0 | 1997 | 7,424 | 2,308 | 8,106 | 5,808 | 0 | 2,298 |
| 1963 | 7,003 | 3,242 | 6,575 | 6,077 | 13 | 485 | 1998 | 10,294 | 3,441 | 9,072 | 6,698 | 2 | 2,372 |
| 1964 | 3,905 | 2,202 | 4,849 | 4,849 | 0 | 0 | 1999 | 7,196 | 3,328 | 7,202 | 6,379 | 0 | 824 |
| 1965 | 6,983 | 3,612 | 5,475 | 4,581 | 0 | 894 | 2000 | 6,839 | 2,985 | 7,074 | 5,573 | 0 | 1,501 |
| 1966 | 5,299 | 3,263 | 5,544 | 5,544 | 0 | 0 | 2001 | 4,141 | 2,200 | 4,824 | 4,823 | 0 | 1 |
| 1967 | 7,404 | 3,506 | 7,066 | 6,131 | 0 | 935 | 2002 | 5,052 | 2,558 | 4,590 | 4,590 | 0 | 0 |
| 1968 | 4,772 | 2,670 | 5,515 | 5,138 | 0 | 377 | 2003 | 6,363 | 3,159 | 5,659 | 5,409 | 0 | 250 |
| 1969 | 7,668 | 3,528 | 6,714 | 5,421 | 0 | 1293 | 2004 | 5,738 | 2,183 | 6,615 | 5,617 | 0 | 998 |
| 1970 | 7,902 | 3,440 | 7,885 | 5,477 | 4 | 2404 | 2005 | 5,639 | 3,035 | 4,692 | 4,475 | 0 | 217 |
| 1971 | 7,328 | 3,275 | 7,402 | 6,824 | 1 | 578 | 2006 | 9,241 | 3,205 | 8,964 | 6,608 | 0 | 2,356 |
| 1972 | 5,078 | 3,267 | 5000 | 5000 | 0 | 0 | 2007 | 3,957 | 1,879 | 5189 | 5166 | 0 | 23 |
| 1973 | 6,167 | 3,317 | 6026 | 5583 | 0 | 443 | 2008 | 3,984 | 1,385 | 4220 | 4178 | 0 | 42 |
| 1974 | 10,796 | 3,658 | 10364 | 6796 | 0 | 3568 | 2009 | 4,533 | 1,774 | 4309 | 4105 | 186 | 18 |
| 1975 | 6,405 | 3,570 | 6384 | 6153 | 0 | 231 | 2010 | 5,646 | 3,319 | 4107 | 4004 | 0 | 103 |
| 1976 | 3,611 | 1,295 | 5813 | 5813 | 0 | 0 | 2011 | 6,468 | 3,341 | 6577 | 5703 | 0 | 874 |
| 1977 | 2,628 | 631 | 3247 | 3247 | 0 | 0 | 2012 | 3,971 | 2591.6 | 5211 | 5209 | 0 | 1 |
| 1978 | 7,837 | 3,428 | 4944 | 4538 | 0 | 407 | 2013 | 3,998 | 1,906 | 4588 | 4587 | 0 | 1 |
| 1979 | 4,022 | 3,141 | 4203 | 4203 | 0 | 0 | **Average** | **5,898** | **2,766** | **5804** | **4958** | **7** | **839** |

Source: Reclamation 2014b

Key:
* = reservoir filling
Sept. = September
TAF = thousand acre-feet

The frequency of flood flows of different magnitudes can be significant for different types of analyses. Table 1-31 summarizes the percentage of years in which Sacramento River flow below Bend Bridge exceeded the specified flow rate one or more times during a month over the recorded historical period.

**Table 1-31. Percentage of Years with Flows in Excess of Specified Flow Rate for Sacramento River Below Bend Bridge by Month (1939-2010)**

| Flow (cfs) | Percentage of Years (%) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Oct | Nov | Dec | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep |
| >100,000 | 0 | 0 | 3 | 8 | 7 | 7 | 3 | 0 | 0 | 0 | 0 | 0 |
| >80,000 | 0 | 0 | 10 | 17 | 13 | 8 | 3 | 0 | 0 | 0 | 0 | 0 |
| >60,000 | 0 | 3 | 19 | 31 | 29 | 21 | 10 | 1 | 0 | 0 | 0 | 0 |
| >40,000 | 0 | 6 | 28 | 43 | 47 | 32 | 14 | 6 | 0 | 0 | 0 | 0 |
| >20,000 | 3 | 19 | 54 | 68 | 78 | 63 | 28 | 21 | 4 | 0 | 0 | 0 |

*Source: USGS Gaging Station 11377100*

Key:
cfs = cubic feet per second
USGS = U.S. Geological Survey

### *Lower Sacramento River and Delta*

Flood management facilities along the lower Sacramento River and in the Delta include the levees, weirs, and bypasses of upper and lower Butte Basin, the Sacramento River between Colusa and Verona, and the Sacramento River between Verona and Collinsville. The levees, weirs, and bypasses are features of the Sacramento River Flood Control Project, which began operation in the 1930s and was significantly expanded in the 1950s.

**Butte Basin** Butte Basin is the northernmost of the natural overflow basins flanking the Sacramento River. Located east of the Sacramento River, it extends from northwest of Chico to the mouth of Butte Slough, north of Meridian. Its eastern boundary is an indefinite line along the gently sloping lands rising from the basin toward the Sierra Nevada foothills.

When Sacramento River flows exceed between 90,000 and 100,000 cfs at Ord Ferry, water flows naturally over the banks of the river into Butte Basin. In addition to the Sacramento River overbank flows at Ord Ferry, the basin receives inflow over the Colusa and Moulton weirs and from tributary streams draining from the northeast, principally Cherokee Canal and Butte Creek. Before construction of the Feather River levees, Butte Basin also received overflows from the Feather River north of the Sutter Buttes. Outflows from Butte Basin move through the Sutter Bypass when the Sacramento River is high or through the Butte Slough outfall gates (RM 139) into the Sacramento River when the river is low.

Butte Basin has a significant attenuation effect on flood flows before they are discharged into the Sutter Bypass downstream from Colusa. Butte Basin holds

more than 1 MAF when in full flow, and water has a travel time of about 2 days from its upper end to the Sutter Bypass.

*Moulton Weir* In 1932, the U.S. Army Corps of Engineers (USACE) constructed Moulton Weir (RM 158), an ungated weir between the towns of Butte City and Colusa. The weir has a 535-foot crest length and 49-foot crest width. The weir spills water from the Sacramento River into Butte Basin when flows in the Sacramento River at the weir exceed 60,000 cfs.

*Colusa Weir* Colusa Weir (RM 146), completed by USACE in 1933, is an ungated weir located between Moulton Weir and the town of Colusa. The weir has a 1,650-foot crest length and 20-foot crest width. The weir starts to discharge excess flows from the Sacramento River into Butte Basin when flows in the river at the weir exceed 30,000 cfs. During a sharp rise on the Sacramento River, Colusa Weir usually begins to pass flows before either the Moulton Weir or Tisdale Weir, approximately 2 hours before the Colusa gage is expected to exceed 59.8 feet (32,000 cfs).

**Sacramento River Between Colusa and Verona** The Sacramento River meanders through the 64 miles between Colusa (RM 143) and Verona (RM 79). The levee system continues along both sides of this river reach. The levee spacing (or channel width), east to west, is wider between the upstream sections, from RM 176 to RM 143 at Colusa, than the levee spacing downstream from Colusa. The Feather River, the largest eastside tributary to the Sacramento River, enters the river just above Verona. Flood management diversions occur at two places in this segment of the river: at the Tisdale Weir and the Fremont Weir.

*Tisdale Weir* In 1932, USACE built the Tisdale Weir, south of Colusa and just downstream from Grimes (RM 119). This ungated weir, with a 1,150-foot crest length and 38-foot crest width, discharges excess flows from the Sacramento River into the Tisdale Bypass, which leads to the Sutter Bypass. The weir starts to discharge excess flow when Sacramento River flows exceed 23,000 cfs. During a slow rise on the river, this weir begins to pass flows before the Moulton and Colusa weirs, 8 to 10 hours after the upstream Colusa gage exceeds 55.0 feet (23,000 cfs). During high flows in the Sutter Bypass, and when the Sacramento River stage is sufficiently lower, flows may leave the bypass and rejoin the river flowing through the Tisdale Bypass over Tisdale Weir.

*Tisdale Bypass* The Tisdale Bypass (RM 119) is a leveed channel that conveys water that has spilled over Tisdale Weir, and routes the water to the Sutter Bypass. As described above, extremely high flows in the Sutter Bypass may flow back into the Sacramento River over Tisdale Weir via the Tisdale Bypass.

*Sutter Bypass* The Sutter Bypass, which began operation in the 1930s, is a leveed portion of the natural floodway in the Sutter Basin. The bypass is located

south of the Sutter Buttes, and runs approximately between and parallel to the Sacramento and Feather rivers. Flows enter the Sutter Bypass from Butte Basin at its upper end near Colusa at Butte Slough. Other flows enter the bypass from the east via the Wadsworth Canal and DWR's drainage pumping plants (No. 1, 2, and 3). Flows exit the Sutter Bypass and combine with the Sacramento River and Feather River upstream from Fremont Weir near the town of Verona.

*Fremont Weir* Fremont Weir (RM 83), completed in 1924 by USACE, is an ungated weir with a 9,518-foot crest length and 35-foot crest width. Fremont Weir is located on the west bank of the Sacramento River where the Sutter Bypass, Feather River, and Sacramento River meet near Verona. Excess flows discharge over the weir into the Yolo Bypass when flows in the Sacramento River at Verona exceed 62,000 cfs.

**Sacramento River Between Verona and Collinsville** Below Verona, the Sacramento River flows 79 miles to Collinsville, at the mouth of the Delta, passing the City of Sacramento along the way. The Yolo Bypass parallels this river reach to the west. Flows enter this river reach at various points. First, flows from the Natomas Cross Canal enter the Sacramento River approximately 1 mile downstream from the Feather River mouth (RM 80). The American River (RM 60), the southernmost major Sacramento River tributary, enters the river at the City of Sacramento. Flows in the Yolo Bypass reenter the river near Rio Vista (RM 12). As the river enters the Delta, Georgiana Slough branches off from the mainstem Sacramento River, routing flows into the central Delta. The one diversion point for flood management is at Sacramento Weir, where floodwaters are diverted from the Sacramento River through the Sacramento Bypass to the Yolo Bypass under the highest flow conditions. The major features that affect flow in this segment of the river are described below.

*Sacramento Weir* In 1916, the City of Sacramento began construction of the Sacramento Weir along the Sacramento River (RM 63) upstream from the American River confluence, immediately west of Sacramento. This weir has a variable crest with 48 removable gates, and net crest length of 1,830 feet. High flows from the Sacramento River are diverted at the weir into the Yolo Bypass via the Sacramento Bypass. When flows from the American River are high enough, some of the American River water flows upstream through the Sacramento River channel to the weir.

The Sacramento Weir is the only weir in the Sacramento flood management system with gates for manual operation during a flood. The weir is operated to limit flood stages in the Sacramento River to project design levels, to reduce sediment in the Sacramento River channel downstream from the weir, to prevent flooding of agricultural lands in the Yolo Bypass until after those lands have been inundated by flows over the Fremont Weir, and to make maximum use of the flood-carrying capacity of the Sacramento River channel downstream from the weir.

DWR operates the weir under rules specified by USACE to achieve the objectives described above. The rules have been in effect since 1940, except from 1963 through 1975, when a higher initial opening level was specified. Where USACE's rules allow flexibility, DWR opens the gates at the minimum stage permitted. Weir opening begins when the stage on the Sacramento River at the I Street gage is 27.5 feet. The procedure for continued operation is to open as many gates as necessary to maintain the stage at the I Street gage at or below 27.5 feet, until all gates are open.

*Yolo Bypass* The Yolo Bypass is a leveed floodway through the natural overflow Yolo Basin on the west side of the Sacramento River between Verona and Rio Vista near Suisun Bay. The bypass flows generally north to south and extends from the Fremont Weir (RM 83) downstream to Liberty Island (RM 14) in the Delta.

During high flows in the Sacramento River, water enters the Yolo Bypass over the Fremont Weir and Sacramento Weir and Bypass and is conveyed south around the City of West Sacramento. During periods of high stage in the Sacramento River, flows from the Colusa Basin are discharged through Knights Landing Ridge Cut to the Yolo Bypass. Additional flows enter the bypass from the westside tributaries, including Cache Creek, Putah Creek, Willow Slough, and the Willow Slough Bypass. Flood waters reenter the Sacramento River upstream from Rio Vista.

The Yolo Bypass floods approximately once every 3 years, generally during the winter months of December, January, and February. However, in 1998, water entered the bypass in June. During the irrigation season, nonflood waters exit the bypass primarily through the east levee toe drain.

*Natomas Cross Canal* The Natomas Cross Canal (RM 79), downstream from the Feather-Sacramento river confluence, collects flows from Coon, Markham, and Pleasant Grove creeks and Auburn Ravine and routes the flows to the Sacramento River. Levees line the canal and split north and south to border the west side of the Natomas East Canal to protect the North Natomas area.

Table 1-32 shows the recurrence of historical spills over each of the Sacramento Valley weirs. A single day of spill in a given year would constitute a year with a spill. Some weirs, like the Tisdale and Colusa weirs, spill almost every year, whereas the Sacramento Weir rarely spills.

**Table 1-32. Number of Years with Spills over Sacramento Valley Weirs**

| Weir Name | Number of Years with Spill |
|---|---|
| Moulton Weir | 49 (66%) |
| Colusa Weir | 62 (84%) |
| Tisdale Weir | 70 (95%) |
| Fremont Weir | 53 (72%) |
| Sacramento Weir | 21 (28%) |

*Source: DWR Bulletin 69-95 (DWR 2003c) with additional information from DWR Flood Systems Analysis Office (DWR 2008)*

Notes:

(%) indicates percent of years in period of record with spill

Period of record: Water years 1935-2008

Key:

DWR = California Department of Water Resources

### *CVP/SWP Service Areas*

This section describes flood management facilities in the CVP/SWP service areas by river basin, including the Feather River, American River, San Joaquin River, and eastside tributaries to the Delta (Littlejohns Creek, Calaveras River, and Mokelumne River).

**Feather River** The primary flood management feature of the Feather River Basin is Oroville Reservoir, with a flood management reservation volume of 750,000 acre-feet. Oroville Reservoir releases are used to help meet the objective flow on the Feather River of 150,000 cfs, and in conjunction with New Bullards Bar Reservoir on the Yuba River, to meet an objective flow below the Yuba River confluence of 300,000 cfs. Levees line the Feather River from its confluence with the Sacramento River up to the City of Oroville (RM 63).

**American River** The lower American River is primarily protected from flooding by Folsom Dam. The Folsom Reservoir flood management reservation volume is variable, ranging from 400,000 acre-feet to 670,000 acre-feet. The objective release on the American River is 115,000 cfs; however, some damage to infrastructure along the American River occurs at flows above 20,000 cfs. The American River is leveed from its confluence with the Sacramento River to near the Carmichael Bluffs on the north bank, and to near the Sunrise Boulevard Bridge on the south bank (RM 19).

**San Joaquin River** The San Joaquin River Basin is protected by an extensive reservoir system, including the following:

- Friant Dam and Millerton Lake (RM 270), with a flood management reservation volume of 170,000 acre-feet
- Big Creek Dam, on Big Creek, with a flood management reservation of 30,200 acre-feet

- Hidden Dam and Hensley Lake on the Fresno River, with a flood management reservation of 65,000 acre-feet
- Buchanan Dam and H.V. Eastman Lake on the Chowchilla River, with a flood management reservation of 45,000 acre-feet
- Los Banos Detention Dam on Los Banos Creek, with a flood management reservation of 14,000 acre-feet
- Merced County Stream Group Project, consisting of five dry dams (Bear, Burns, Owens, Mariposa, and Castle) and two diversion structures, with a total flood storage capacity of 30,500 acre-feet
- New Exchequer Dam and Lake McClure on the Merced River, with a flood management conservation of 350,000 acre-feet
- Don Pedro Dam and Lake on the Tuolumne River, with a flood management conservation of 340,000 acre-feet
- New Melones Dam and Lake on the Stanislaus River, with a flood management reservation of 450,000 acre-feet

**Eastside Tributaries to the Delta** The streams in the northern portion of the San Joaquin River Basin, between the American and Stanislaus rivers, are commonly referred to as the eastside tributaries to the Delta. These rivers flow into the San Joaquin River within the boundaries of the Delta. Flood management features on the eastside tributaries to the Delta include the following:

- Farmington Dam and Reservoir on Littlejohns Creek, with a flood management reservation of 52,000 acre-feet
- New Hogan Dam and Lake on the Calaveras River, with a flood management reservation of 165,000 acre-feet
- Camanche Dam and Reservoir on the Mokelumne River, with a flood management reservation of 200,000 acre-feet

### 1.1.6 South Delta Water Levels

This section discusses the variability of water levels in the south Delta, as part of CVP/SWP operations in the extended study area.

#### *Lower Sacramento River and Delta*

In the south Delta, decreases in water levels due to CVP and SWP export pumping are a concern for local agricultural diverters, because during periods of low water levels, sufficient pump draft cannot be maintained and irrigation can be interrupted. Historically, the highest minimum stage in the Middle River

typically occurs in February and is about 0.1 foot below msl. The lowest minimum stage typically occurs in August and is about 0.8 foot below msl. During dry and critical years, under existing conditions, the highest minimum stage in the Middle River typically occurs in April and is about 0.6 foot below msl. The lowest minimum stage typically occurs in September and is about 0.7 foot below msl (CALFED 2000).

*This page left blank intentionally.*

# Chapter 2
# Modeling Results

As described in Chapter 6 of this EIS, extensive modeling was conducted to support technical analysis of the SLWRI alternatives. Modeling of the CVP and SWP systems was conducted using CalSim-II to determine flow and storage changes. Delta Simulation Model 2 (DSM2) was used to determine Delta water-level changes. Detailed modeling results for CalSim-II are presented in Attachment 1 of the Modeling Appendix. Detailed modeling results for DSM-2 are presented in Attachments 16 and 17 of the Modeling Appendix.

*This page left blank intentionally.*

# Chapter 3
# References

Borthwick, S.M., and R.R. Corwin. 2001. Wild fish entrainment by Archimedes lifts and an internal helical pump at the Red Bluff Research Pumping Plant, Upper Sacramento River, California: February 1997–May 2000. Red Bluff Research Pumping Plant Report Series, Volume 13. Bureau of Reclamation, Red Bluff, California

CALFED Bay-Delta Program. 2000. Final Programmatic EIS/EIR for CALFED Bay-Delta Program. August.

CALFED. *See* CALFED Bay-Delta Program.

California Data Exchange Center. California Department of Water Resources stream gage data Web site: http://cdec.water.ca.gov/

California Department of Water Resources. 1998. Bulletin 160-98. Department of Water Resources, California Water Plan Update. November.

———. 1999. California State Water Project Atlas.

———. 2003a (May). Settlement Agreement by and Among the Planning and Conservation League, Plumas County Flood Control and Water Conservation District, Citizens Planning Association of Santa Barbara County, Inc., and the State of California Department of Water Resources, Kern Water Bank Authority, and those State Water Project Contractors Identified Herein.

———. 2003b. Bulletin 118. Department of Water Resources, California's Groundwater. October.

———. 2003c. Bulletin 69-95. Department of Water Resources, California High Water. October.

———. 2005. Bulletin 160-05. Department of Water Resources, California Water Plan Update. December.

———. 2006. Bulletin 132-05. Department of Water Resources, Management of the California State Water Project. December.

CDEC. *See* California Data Exchange Center.

DWR. *See* California Department of Water Resources.

Gaines, and Martin. 2002. Abundance and seasonal, spatial, and diel distribution patterns of juvenile salmonids passing the Red Bluff Diversion Dam, Sacramento River. Final Report Red Bluff Research Pumping Plant, Report Series: Volume 14. U.S. Fish and Wildlife Service. Red Buff, California.

Interagency Ecological Program. 2011. Interagency Ecological Program Dayflow Calculation data from: http://www.iep.ca.gov/dayflow/index.html

National Marine Fisheries Service. 1993. Biological Opinion for the Operation of the Federal Central Valley Project and California State Water Project.

NMFS. *See* National Marine Fisheries Service.

Reclamation and DWR. *See* U.S. Department of the Interior, Bureau of Reclamation, and California Department of Water Resources.

Reclamation. *See* U.S. Department of the Interior, Bureau of Reclamation.

Shasta County Water Agency. 1998. Coordinated AB 3030 Groundwater Management Plan for the Redding Groundwater Basin, Shasta County Water Agency. November

Tehama GMP. 1996. Tehama County Flood Control and Water Conservation District Coordinated AB 3030 Groundwater Management Plan, Dan Keppen and Scott Slater. November

Tehama-Colusa Canal Authority and Reclamation. 2002. Draft EIS/EIR Fish Passage Improvement at the Red Bluff Diversion Dam.

U.S. Army Corps of Engineers. 1977. Shasta Dam and Lake, Sacramento River, California Report on Reservoir Regulation for Flood Control, Rev. January.

U.S. Army Corps of Engineers. 1999. Sacramento and San Joaquin River Basins, California Post-Flood Assessment, U.S. Army Corps of Engineers, Sacramento District. March.

U.S. Department of the Interior, Bureau of Reclamation, and California Department of Water Resources (Reclamation and DWR). 2003. Environmental Water Account (EWA) Draft Environmental Impact Statement/Environmental Impact Report. July.

U.S. Department of the Interior, Bureau of Reclamation. 2000.

———. 2004. Long-Term Central Valley Project Operations Criteria and Plan (CVP-OCAP) Biological Assessment. June.

———. 2011. Central Valley Project Operations Web site: http://www.usbr.gov/mp/cvo/index.html———. 2013. CVPIA Long-Term Water Service Contract Web site: http://www.usbr.gov/mp/cvpia/3404c/lt_contracts/index.html

———. 2014. Central Valley Project Water Contractors. March. http://www.usbr.gov/mp/PA/water_contractors/latest_Water_Contractors.pdf

———. 2014b. Central Valley Project Operations Web site: http://www.usbr.gov/mp/cvo/index.htmlU.S. Geological Survey. Gaging Stations data from http://waterdata.usgs.gov/nwis/sw

USACE. *See* U.S. Army Corps of Engineers.

USGS. *See* U.S. Geological Survey.

## 3.1 Personal Communications

### 3.1.1 Chapter 1 Affected Environment

California Department of Water Resources. 2008. From Brian Heiland, DWR Flood Systems Analysis Office, via e-mail. April.

U.S. Department of the Interior, Bureau of Reclamation. 2011. From Russ Yaworsky, Central Valley Project Operations, via e-mail.

*This page left blank intentionally.*